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The Topography of Demography's Impact on Inflation

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The views stated in this thesis are those of the author and not necessarily those of the supervisor, second assessor, Erasmus School of Economics or Erasmus University Rotterdam.

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Contents

1 Introduction

In an analysis of East Asia's economic boom in the second half of the 20th century, (D. E. Bloom & Williamson, 1998) found that almost a third of the economic growth could be attributed to demographic variables. Declines in the mortality rate, rising life expectancy, and policies that allowed economies to fully metabolize the demographic transition created tremendous economic advances and pulled what were, at the time, some of the poorest countries in the world into quintessential models for rapid economic growth. The effects of a demographic transition were not limited to developing economies - starting in the 1980s, Ireland experienced a similar demographic transition after a series of policy changes and similarly experienced an economic boom. Falling birth rates through the legalization of contraceptives and large increases in female labor force participation led to decreases in the youth dependency ratio and an increase in the number of working age individuals relative to the rest of the population. Combined with an open economic model and large investments in human capital, Ireland saw economic growth comparable to the miracle economies of Asia (D. Bloom, Canning, & Sevilla, 2003).

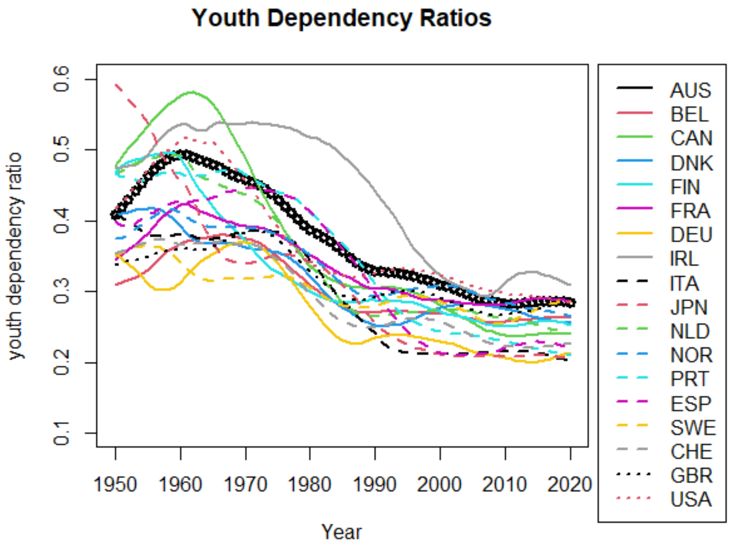
The East Asian and Irish economic booms demonstrate the important, but often slow-moving, impact demographic structures can have on an economy. It has been well recorded that large imbalances in societal age structures have immense impacts on economically relevant variables, but there is still significant disagreement over the magnitude of the effect, and with some variables even whether the economic impact is associated with a positive or negative coefficient.

Fundamentally, the way the age structure of a country impacts the economy is through changes in the demographic structure working their way through the population pyramid over time. It is the relative difference between age groups that determines the impact demography has on an economy.These effects are therefore purely transitory; in the population structure that results in a demographic dividend, for example, the dependent and working-age populations grow at different rates in such a way that the dependant proportion of the population shrinks relative to the working-age portion (D. E. Bloom & Williamson, 1998). This is usually the result of declines in child mortality rates and increasing life expectancy. If children are more likely to survive infancy and live longer, parents will have less children and invest more resources per child. This results in reductions in the fertility rate until eventually new generations are equal to, or smaller than, existing generations. At that point, the working age population becomes larger than the population that will replace them - this results in a society that has more workers than ever needing to invest less in training younger generations than ever before. This is the effect that played a significant role in fueling the East Asian and Irish economic booms.

Eventually, the large working age cohort will age into retirement and the demography will go from paying dividends to requiring retirement benefits. Many parts of the world, especially but not exclusively developed economies, experienced a similar demographic formation as the East Asian "tiger economies" and Ireland through the baby boom generation. Almost unanimously across the developed word, and to a degree in the developing world, the generation born in the decades after World War 2 went on to have fewer children themselves than their predecessor generations. Most economies outside of Sub-Saharan Africa have seen sharp increases in their median ages as a result. The forecasts for economies around the world is one of increasing old age dependency ratios and declines in prime age workers as a percent of the population, and in almost all economies, immigration will not be sufficient to compensate for the changes in labour supply (Narciso, 2010).

The demographic dividend is just one of many age structures that have been studied for their impact on economic growth. Almost every country has experienced relative differences in age structures due to variations in generational differences in fertility rates, mortality rates, and life expectancy.

The power of demographic transitions to alter the economic landscape has been widely researched,



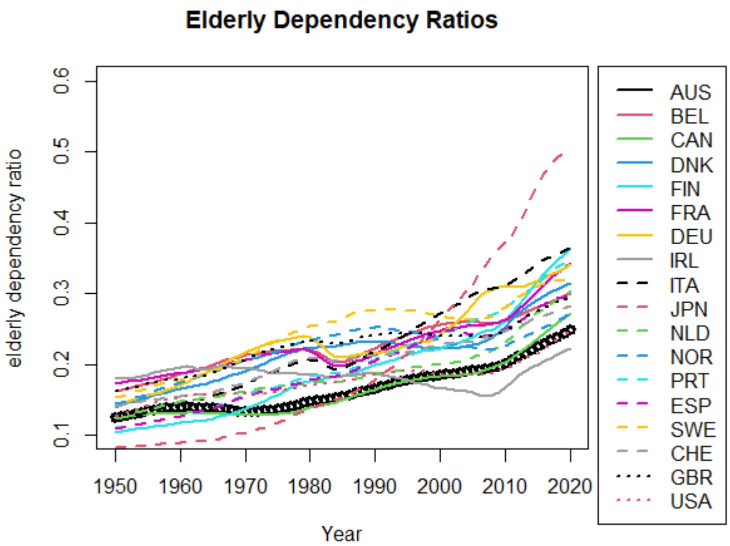


Figure 1: Age Dependency Ratios Over Time

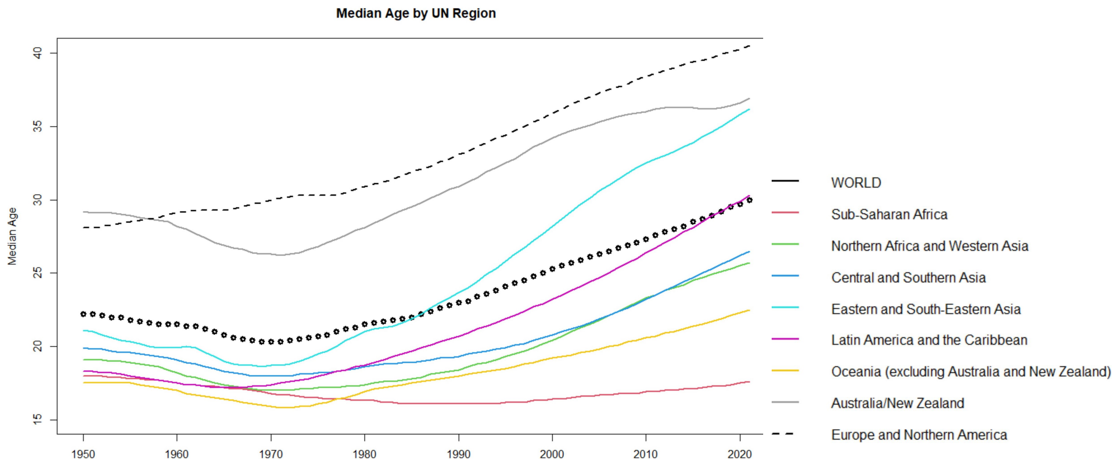


Figure 2: Median Age by UN Region over Time
Source: United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022, Online Edition

but many aspects of the relationships between age structures and economic variables remain poorly understood regarding the particular details. This paper will focus on the impact of demographic structures on inflation, wherein there is still dispute regarding the directional impact certain parts of the population structure have on inflation. This paper seeks to answer the question: what is the contemporaneous impact of an economy's demographic structure on inflation as measured by changes in the consumer price index. This question will be be investigated through an analysis of the impact of demographic variables in terms of their level and their rate of change through the perspective of panel and quantile regressions.

This paper reaffirms the results of (Broniatowska, 2019; Yoon, Kim, & Lee, 2014), finding strong evidence that increases in the level of youth dependency are inflationary and increases in level of elderly dependency are deflationary. Evidence is found for non-linear characteristics in the relationship of the youth dependency ratio and the elderly dependency ratio with inflation. Higher levels of the elderly dependency ratio are generally found to be increasingly associated with deflation up to a point - around a level of 0.17 - at which coefficient estimates for the deflationary impact of higher levels in the old age dependency ratio stabilize to a constant.

Decreases in the youth dependency ratio are strongly associated with a relatively small deflationary impact that is consistent no matter the size of the decline. Changes in the old age dependency ratio and increases in the youth dependency ratio are generally not found to have an impact on contemporaneous changes in inflation, except in the most extreme cases. Very large increases in the youth dependency ratio and elderly dependency ratio are weakly associated with small spikes in inflation and deflation, respectively. The impact to inflation of contemporaneous changes in the dependency ratios are found to be far less impactful than the level of the dependency ratio.

The rest of the paper is organised as follows. Section 2 will review parts of the existing literature on measuring the relationship between demography and inflation. Section 3 describes the data used. Section 4 investigates the link between inflation and demography. Subsection 4.2 establishes a baseline model and analyzes the impact of demographic dependency levels on inflation. Subsection 4.5 adapts the regressions to investigate how the rate of demographic change affects inflation. Subsection 4.6 provides an alternative specification with additional controls under which the regressions of the preceding sections are recreated. Section 5 discusses the findings and conclusions while Section

6 notes the limitations of those conclusions.

2 Literature Review

2.1 Demographics and Economics

At the core of every economy are individuals who work, consume, invest, and retire. The way many of these activities are conducted differ with the age of the individual. The Life Cycle Theory of (Modigliani & Brumberg, 1954) provides a testable economic premise: the young save for retirement while the old live off of their savings. The Life Cycle Investment Hypothesis informs the financing mechanics of the Life Cycle theory - agents borrow in their youth, invest as they age, and then convert those investments into consumption in retirement. (Favero, Gozluklu, & Yang, 2016)

Discussions about the relationship between demographics and an economy are generally channeled to other variables: either through the changes in savings or changes in consumption. (Higgins & Williamson, 1996) find that countries with higher youth dependency ratios experience higher investment demand and lower national savings. This combination is associated with a current account deficit as capital is imported from abroad to finance investment in the growing labour force. Conversely, decreases in dependency ratios depresses investment more than savings, leading to capital export. Changes in the demographic structure of an economy can thus lead to changing demands for savings and investment as the relative difference between the amount of dependants to the amount of workers shifts.

Population growth has generally been found to be negatively associated with economic growth, largely as population growth results in an economy equipping new workers rather than increasing productivity per worker (Galor & Weil, 2000). The impact does not appear to be universal, however, as in developed economies, urbanization density can negate the negative impact on economic growth often associated with population growth (Becker, Glaeser, & Murphy, 1999). Increases in population health are unambiguously associated with economic growth (Barro, 2013). Additionally, increases in longevity are associated with higher savings rates for all ages while decreasing longevity is associated with declines in savings rates (D. E. Bloom, Canning, & Graham, 2003). Changes in the proportion of young to old in rapidly growing economies has also been shown to change savings rates through wage differentials between young and old (Fry & Mason, 1982; Mason, 1988).

The important role age structures play in determining savings and investment rates exemplifies how demographic variables can play a meaningful role in predicting various economic and financial phenomena. The relationship between demographics and savings rates has been used to explain significant portions of the savings booms in India, East Asia, and Eastern Europe throughout the 20th century (Coale & Hoover, 1958; D. E. Bloom et al., 2003; Higgins & Williamson, 1996). Demographic dependency ratios are statistically significant in predicting international capital flows for foreign direct investment and foreign portfolio investment (Narciso, 2010). (Goyal, 2004) found that demographic dependency ratios are statistically significant in predicting long-run stock market returns.

2.2 Demographics and Inflation

A large body of research, starting in the latter half of the 1990s, has investigated the particular impacts of demography on inflation. A number of channels have been theorized to exist through which demographics may act on price levels in an economy. Demographic variables have been found to account for significant proportions of the variation in long-run inflation - (Juselius & Takáts,

2015) estimated that demographic factors accounted for approximately one third of the variation in inflation in the latter half of the 20th century.

The exact mechanism through which inflation is impacted by demographic factors remains in dispute. (Broniatowska, 2019) identifies 2 contradictory streams in the literate: a "traditional" view based in the life-cycle hypothesis in which ageing is inflationary and a "new" view based on changes in consumption patters that view ageing as deflationary. The traditional view predicts that ageing will result in reductions in fiscal surpluses as old age benefits and healthcare costs increase as the tax base shrinks (Katagiri, Konishi, & Ueda, 2020). The new view predicts that changing consumption patters from ageing populations will result in deflationary pressures through declining GDP growth and falling prices (Anderson, Botman, & Hunt, 2014; Gajewski, 2015).

(Anderson et al., 2014) find that the deflationary pressure of ageing is primarily the result of changes in relative prices, and that the effect is amplified by the dissaving by the elderly. (Gajewski, 2015) use panel fixed effects and panel corrected standard error models on an array of dependency ratios and find evidence of youth dependency ratios being inflationary and elderly dependency being deflationary.

There also exists a political economy view, whose founding is often attributed to (Bullard, Garriga, Waller, et al., 2012), that exists parallel to the traditional and new view, wherein central bank policy is influenced by the inflation preferences of the dominant political demographic. The young prefer inflation to wear away at the debts they build up to invest and consume while the elderly prefer very low inflation as they have largely paid off their debts and increasingly rely on savings that are sensitive to inflationary pressures (bonds, pensions, government programs, and other forms of fixed-income). In including political considerations, (Katagiri, Konishi, & Ueda, 2014) developed a model which found the effects of ageing are dependant on the cause of the ageing: increases in-longevity are deflationary while declines in birth rate are inflationary. Juselius and Takats have noted disagreement with the Bullard's political economy model, however, citing their finding of a structural break in central bank policy in the mid 1980s where their policy began mitigating demographic trends rather than supporting them, and that the elderly are inflationary rather than deflationary (Juselius & Takáts, 2015, 2018).

In a review of ageing's impact on inflation and monetary policies using population polynomials, (Juselius & Takáts, 2015) conclude that ageing is likely to lead to higher, rather than lower, inflation. In a 2018 paper, they affirm their findings that rising youth dependency is inflationary and increases in the working age ratio are deflationary. The results for elderly dependency are found to be somewhat more ambiguous as old age dependency is generally found to be inflationary but with high uncertainty, except for the 80+ category which is found to be deflationary.

2.3 This Paper's Relevance

Throughout most of the literature which investigates demography's impact on an economy, demography has largely only entered into economic models through size (D. E. Bloom et al., 2003). As far as the author is aware, this paper is the first to investigate inflation is impacted across the distribution of dependency ratios. The age structure of an economy has been shown to impact how transmittable monetary policy shocks are to consumption in an economy (Sterk & Tenreyro, 2018; Wong, 2018; Leahy & Thapar, 2019), thus a deeper understanding of how the level of dependency and the rate of change of those dependency structures in an economy can help to further refine policy-makers' decision making in the context of their economy's demography.

3 Data

This paper's analysis covers 18 developed countries included in Jorda, Shularick, and Taylor (2017)'s (JST2017) macroeconomic database (Australia, Belgium, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, UK, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Sweden, & USA). Although JST2017's economic data extends from 1870 to 2017 for most countries, data availability contraints for certain variables and other datasets restricts this paper's analysis to 1950-2017. Inflation, denoted as $cpi_{i,t}$, will be defined as annual changes in that country's consumer price index as reported in JST2017.

Demographic structures will be proxied through young age dependency ratio, $ydep_{i,t}$, and old age dependency ratio, $odep_{i,t}$. Index $i = 1, ..., N$ is a country index for each of the 18 countries in the panel while index $t = 1, ..., T$ is the time index for each of the 67 years in the panel. The young age dependency ratio is constructed by dividing the number of people aged as young dependants (0-14) in a country by the number of people in the country who are of prime working age (15-64). The old age dependency ratio is calculated by dividing the number of people aged as elderly dependants (65+) in a country by the number of people in the country who are of prime working age. All population data comes from the 2022 revision of the United Nations' World Population Prospects and covers the periods from 1950-2022.

Over 1950-2017, the developed world has experienced a largely synchronous trend towards increasing old age dependency ratios and decreasing youth dependency ratios. For example, in 1950, no country in the sample had an old-age dependency ratio above 0.20. By 2017, every country in the sample had an old age dependency above 0.20. This synchronous ageing limits cross-country variation and can lead to identification problems as short term trends in inflation and age structure may be misconstrued as long run relationships (Juselius & Takáts, 2018). The limited cross-country variation can be controlled to a degree through the use of control variables, time effects, and the use of a variety of regression models. The relatively uniform experience of increasing life expectancy, decreasing mortality rates, increasing old age dependency, and decreasing youth dependency across countries thus limits the universality of any conclusions drawn.

A number of other variables are used throughout there regressions to control for other factors that may be underlying low-frequency changes in inflation. The annual percent change in real GDP per capita, $rgdppc_{i,t}$, annual percent change in the broad money supply, $money_{i,t}$, annual percent change in a country's terms of trade, $ToT_{i,t}$, and the annual change in the government budget balance as a percent of GDP, $budbal_{i,t}$. The budbal variable is made by subtracting the nominal expenditures variable from the nominal revenues variable of JST2017 and dividing by nominal GDP. As a result, a positive value for $budbal_{i,t}$ indicates a budget deficit while a negative value represents a budget surplus. The ToT index is made by dividing the price level of exports by the price of level of exports, and taking the one period log-difference. The price levels for imports and exports come from version 10.0 of the Penn World Tables (Feenstra, Inklaar, & Timmer, 2015). The data for all other listed variables comes from JST2017.

In the alternative specifications of the regression models, the annual percent change in population, $pop_{i,t}$, the annual change in life expectancy for those aged 60 or less, $LifeExp_{i,t}$, the annual change in mortality rate for those under age 5, $Mortality_{i,t}$, and deviations from an HP-Smoothed trend of the prime labour force participation rate, $LFPR_{i,t}$, are also as controls. The prime age labour force participation rate is constructed by dividing the total employed member of an economy, as reported in JST2017, by the number of prime age workers (15-64) in that economy for that year. An HP filter of $\lambda = 100$ is then used to find the trend, and the value of the prime age labour force participation rate less the trend value for that year is used as $LFPR_{i,t}$. All variables except the total number of employed people come from United Nations demography data.

All percentages without a % sign in this paper are in terms of basis points (i.e. 0.0573 represents 5.73%). Descriptive statistics for relevant variables can be found in Table 1.

4 Emprical Analysis

4.1 Unit Root and Cross-Sectional Dependence Tests

Cross sectional dependence in conventional panel estimators can lead to misleading results or inconsistent estimators, depending on the cause of the cross-sectional dependence, particularly in macro panels with long time series (Chudik & Pesaran, 2013). Cross-sectional dependence in macro panels tends to be the rule, rather than the exception, as the trends and forces influencing one economy are often also active in others, particularly when the economies are similar. To safeguard against the impacts cross-country dependence may have on results, precautions are taken to protect against it.

(Pesaran, 2007)'s cross-sectionally augmented version of the Im-Pesaran-Shin Unit Root Test (IPS) is implemented to check for unit roots in the regression variables. (Im, Pesaran, & Shin, 2003) is a second-generation panel unit root test with a null hypothesis that the variable has a unit root and is robust against cross-sectional dependence. The results of the IPS Test can be found in Table 2. The test finds that all variables are not root explosive and trend stationary.

In cases where cross-sectional dependence is found and N < T, the common procedure is to re-frame the problem as a system of seemingly unrelated equations (SURE) and then estimate the system by the Generalized Least Squares Technique (Zellner, 1962). This will be conducted through the use of a Feasible Generalized Least Squares (FGLS) estimation for all the non-quantile regression sets.

4.2 Broniatowska Regressions

To ascertain the impact demographic ratios have on low-frequency inflation, the regression models of (Broniatowska, 2019), which are themselves inspired the regressions of (Yoon et al., 2014), are reconstructed as a baseline model.

The panel ordinary least squares (OLS) model is defined as:

$$cpi_{i,t} = \mu + \mu_i + \beta_1 ydep_{i,t} + \beta_2 odep_{i,t} + \beta_3 money_{i,t} + \beta_4 rgppc_{i,t} + \beta_5 ToT_{i,t} + \beta_6 budbal_{i,t} + \varepsilon_{i,t} \tag{1}$$

The fixed effects (FE) model is defined as:

$$cpi_{i,t} = \beta_1 ydep_{i,t} + \beta_2 odep_{i,t} + \beta_3 money_{i,t} + \beta_4 rgppc_{i,t} + \beta_5 ToT_{i,t} + \beta_6 budbal_{i,t} + \Sigma_{\forall i}\lambda_i d_i + \Sigma_{\forall t}\lambda_t d_t + \varepsilon_{i,t} \tag{2}$$

Where d_i and d_t are dummy variables to control for country and time, respectively.

The feasible generalized least squares (FGLS) model is composed of:

$$cpi_{i,t} = \mu + X_{i,t}\beta + \varepsilon_{i,t} \tag{3}$$

Where:

$X_{i,t} = [ydep_{i,t}, odep_{i,t}, money_{i,t}, rgppc_{i,t}, ToT_{i,t}, budbal_{i,t}]$

$\widehat{\Omega}$ is the covariance matrix found from the residuals of an OLS regression on the model specified in (3). y represents observations of $cpi_{i,t}$ as vector. From there, the following are estimated:

Variable	Description	Obs.	Average	Variance	Min	Max
Cpi	Annual percent change in national consumer price index	1224	0.04249	0.04165	-0.0458	0.3212
ydep	population aged 0-14 divided by population aged 15-64	1278	0.3380	0.08638	0.2016	0.5923
ydep	population aged 65+ divided by population aged 15-64	1278	0.20029	0.05339	0.0822	0.4513
d_ydep	YoY change in ydep	1224	-0.00230	0.00525	-0.0238	0.0135
d_odep	YoY change in odep	1224	0.00252	0.00278	-0.0083	0.0213
log(ydep)	natural log of ydep	1278	-1.1290	0.00525	-1.6093	-0.5236
log(odep)	natural log of odep	1278	-1.6232	0.00278	-2.5023	-0.6818
Δ log(ydep)	YoY percent change in ydep	1260	-0.00699	0.01437	-0.0568	0.0340
Δ log(odep)	YoY percent change in odep	1260	0.01208	0.01113	-0.0380	0.0506
Money	YoY percent change in broad money	1176	0.08426	0.05940	-0.0924	0.6617
rgdppc	YoY percent change in Real GDP per capita	1224	0.024144	0.02630	-0.0911	0.2142
IapoGDP	YoY percent change in Imports as a percent of GDP	1206	0.25836	0.15194	0.0387	1.0523
budbal	YoY Change in government deficit as a percent of GDP	1224	-0.0001	0.016667	-0.1479	0.0856
ToT	YoY percent change in terms of trade	1242	-0.00047	0.04065	-0.2799	0.3501
Pop	Annual percent change in the total population of a country	1242	0.00688	0.00552	-0.0073	0.0284
rtfpna	Annual percent change in total factor productivity at constant 2017 national prices	1170	0.00991	0.01973	-0.0886	0.1613
LFPR	Deviation of the prime labour force (15-64) participation rate from HP Filter trend.	1260	0.00000	0.01086	-0.0518	0.0488

Table 1: Descriptive Statistics of Model Variables

Table 2: Results of IPS Unit Root Test

Variable	*With intercept*			*With Trend & Intercept*		
	lags	t-bar	p-value	lags	CIPS	p-value
cpi	1	−4.8820	< .01	1	−5.187	< .01
ydep	1	−5.8057	< .01	1	−5.854	< .01
odep	1	−3.1586	< .01	1	−3.5155	< .01
log(ydep)	1	−5.7274	< .01	1	−5.8861	< .01
log(odep)	1	−3.0549	< .01	1	−3.3481	< .01
$\Delta log(ydep)$	1	−2.8608	< .01	1	−2.9084	< .01
$\Delta log(odep)$	1	−2.5652	< .01	1	−2.7595	0.0429
money	1	−2.5652	< .01	1	−4.8956	< .01
rgdppc	1	−5.1586	< .01	1	−5.3040	< .01
ToT	1	−7.1811	< .01	1	−7.2501	< .01
budbal	1	−6.6907	< .01	1	−6.7026	< .01
pop	1	−2.7390	< .01	1	−3.0446	< .01
LifeExp	1	−7.4085	< .01	1	−7.6179	< .01
mortality	1	−7.8763	< .01	1	−7.7971	< .01

$\widehat{\beta}_{FGLS} = (X^T\widehat{\Omega}^{-1}X)^{-1}X^T\widehat{\Omega}^{-1}y$
$\widehat{\Sigma}_{FGLS} = \widehat{\sigma}^2_{FGLS}(X^T\widehat{\Omega}^{-1}X)^{-1}$
$\widehat{\sigma}^2_{FGLS} = [y^T(\widehat{\Omega}^{-1} - \widehat{\Omega}^{-1}(X^T\widehat{\Omega}^{-1}X)^{-1}X^T\widehat{\Omega}^{-1})y]/(T-N)$

$\widehat{\Sigma}_{FGLS}$ is the estimated covariance matrix of β_{FGLS}. A within-transformation is also applied to the FGLS model to achieve a FGLS-within model:

$$cpi_{i,t} = X'_{i,t}\beta + \varepsilon_{i,t} \tag{4}$$

Where: $X' = [ydep_{i,t}, odep_{i,t}, money_{i,t}, rgppc_{i,t}, ToT_{i,t}, budbal_{i,t}, \Sigma_{\forall i}d_i, \Sigma_{\forall t}d_t]$

The results of the regressions can be found in Table 3. The signs of the regressions are consistent with the findings of (Broniatowska, 2019) and (Yoon et al., 2014), with the exception of the coefficients for budget balance, budbal, and the FGLS coefficient for Terms of Trade changes, ToT. The regression results provide strong evidence that higher levels of the youth dependency ratio, ydep, are inflationary and higher levels of the old age dependency ratio, odep, are deflationary.

The positive coefficient associated with ydep is found to be positive at the 1% level across all but the fixed effects regressions. This in-line with the findings of earlier research and reinforces a result consistent throughout the literature that higher ratios of non-working age youths increase the annual expected inflation in a country. All else equal, a ten percent increase in the youth dependency ratio (+0.10) is associated with an increase in inflation of 0.807% - 1.042%. The high end of this estimate comes from the OLS regression without time fixed effects. The addition of time controls in the FE regression or the use of FGLS results in a consist coefficient estimate of approximately 0.80%.

The sign on odep is negative, as is found by other papers using dependency ratios, but not statistically significant except in the FE and FGLS equations. The statistical significance of odep in the FGLS equation, but not in the other regression models, suggests that cross-country dependency may be quite strong. Variance in the significance of the elderly dependency ratio by model type was also found in (Gajewski, 2015), whose panel fixed effects model also found negative coefficients but was not able to find statistical significance. The implementation of a PCSE model which corrects for serial correlation reaffirmed the negative coefficients and found them to be statistically significant. The cross-sectional dependency tests of (Pesaran, 2004) and (Breusch & Pagan, 1980)

	OLS (1)	FE (2)	FGLS (3)	FGLS-within (4)
(Intercept)	-0.0101		0.0138^{***}	
	(0.0197)		(0.0041)	
ydep	0.1042^{***}	0.0807^{*}	0.0810^{***}	0.0813^{***}
	(0.0361)	(0.0433)	(0.0076)	(0.0044)
odep	-0.0084	-0.0744^{*}	-0.0931^{***}	-0.0716^{***}
	(0.0466)	(0.0433)	(0.0270)	(0.0093)
money	0.3386^{***}	0.1559^{***}	0.2857^{***}	0.1560^{***}
	(0.0594)	(0.0391)	(0.0067)	(0.0016)
rgdppc	-0.3814^{***}	-0.3277^{***}	-0.4080^{***}	-0.3279^{***}
	(0.0789)	(0.0664)	(0.0085)	(0.0025)
ToT	-0.0302	0.0037	-0.0232^{***}	0.0035^{***}
	(0.0312)	(0.0314)	(0.0040)	(0.0012)
budbal	0.0327	0.0305	0.0109	0.0302
	(0.0719)	(0.0667)	(0.0098)	(0.0025)
Num. obs.	1176	1176	1176	1176
Country Effects	yes	yes	yes	yes
Time Effects	no	yes	no	yes
R^2	0.2999	0.4897	0.3433	0.4471
Adj. R^2	0.2963	0.4768		

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Standard errors for OLS (1) and FE (2) are HAC robust standard errors

Table 3: ydep and odep Ratio Results

are implemented to determine if cross-country dependency is playing a role. The results thereof can be found in table 4. The results show strong evidence for cross-sectional dependency in the panel data.

As for the differences in results, (Broniatowska, 2019) finds budget balance to be associated with a negative coefficient throughout her regressions. This paper's result of positive coefficients aligns with the results of (Yoon et al., 2014) in sign, but not in significance. The inability to show a statistical difference from zero in this paper's regressions makes the difference a moot point. Although (Broniatowska, 2019) found a positive coefficient for ToT on her GLS regression, the coefficient was not statistically significant. A statistically significant negative coefficient estimate aligns more with the findings of (Yoon et al., 2014).

To determine the fit of the regressions, a number of tests are run to determine how well the regressions fit the data. The results of these tests can be found in Table (4). The Jaque-Bera (JB) test is used to find out if regression residuals are normally distributed (H0: Residuals are normally distributed). The Breusch-Pagan (BP) test is used to test for heteroskedasticity in the residuals. As all regressions rejected the null hypothesis of the JB test, a studentized version of the BP test proposed by (Koenker, 1981), which is robust to non-Gaussian errors, is implemented. The Durbin-Watson (DW) and Breusch-Godfrey (BG) tests are conducted to assess evidence of serial auto correlation in the residual term.

The results of the tests for regression fit show strong evidence of heteroskedasticity and serial autocorrelation in the error terms. Heteroskedasticity and Autocorrelation (HAC) robust standard errors are therefore used when determining regression results.

	OLS (1)	FE (2)	FGLS (3)	FGLS-within (4)
Jaque-Bera Test for Normally Distributed Residuals				
X^2	1018	1487	1047	392
df	2	2	2	2
p	0.0000	0.0000	0.0000	0.0000
Studentized Breusch-Pagan Test for Homoskedastic Residuals				
BP	238.73	218.97	238.73	171.23
df	23	29	23	12
p	0.0000	0.0000	0.0000	0.0000
Durbin-Watson* Test for no auto-correlation in residuals				
DW	0.8749	0.8770	0.7812	0.8627
df	6	6	6	6
p	0.0000	0.0000	0.0000	0.0000
Breusch-Godfrey Test for no serial auto-correlation in residuals				
Chi^2	475.16	354.51	493.06	396.49
df	10	10	10	10
p	0.0000	0.0000	0.0000	0.0000
Breusch-Pagan LM Test for no cross-sectional Dependence				
LM	2504	1787	2658	2592
df	153	153	153	153
p	0.0000	0.0000	0.0000	0.0000
Pesaran's CD Test for no cross-sectional Dependence				
CD	47.628	37.828	46.080	48.162
p	0.0000	0.0000	0.0000	0.0000

*modified BFN Panel Durbin-Watson Test for FGLS (3) and FGLS-Within(4)

Table 4: Tests for Regression Fit

4.3 Quantile Broniatowska Regressions

Quantile Regression, as proposed by (Koenker & Bassett Jr, 1978), can provide meaningful insights into demography's relationship with inflation by analyzing how changes in the level of demographic dependency impact inflation across the distribution of the dependency ratio. Aside from providing a view of the relationship between a set of variables across the distribution of the independent variables, quantile regressions are more robust to outliers and non-normality than OLS regressions. The lack of distribution assumptions for quantile regressions means the features that can make time series economic data hostile to OLS can provide meaningful insights into the relationship between variables in a quantile regression.

The quantile regression estimator is found by solving for the the following minimization problem:

$$\beta_{QR} = argmin[\Sigma_{Y_{it} > \beta X_{it}} \tau |Y_{i,t} - \beta X_{i,t}| + \Sigma_{Y_{it} < \beta X_{it}} (1 - \tau)|Y_{i,t} - \beta X_{i,t}] \forall \tau \in (0, 1)$$

In the equation above, τ refers to the specified decile. Quantile regression is frequently used to analyze the marginal effects under the conditional quantiles at the extreme ends of the data (a common quantile distribution is $\tau \in (0.05, 0.1, 0.25, 0.5, 0.75, 0.90, 0.95)$, ex: (Pham & Vo, 2021)). In this paper, the utility of quantile regressions will be in analyzing how coefficient estimates change over a uniform distribution over the entirety of the data. As such, $\tau \in (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9)$ throughout this paper.

The specification for the first quantile regression is that of equation (1) with country and time controls. The results of the quantile regression can be found in Table 5 and a graphical depiction of the coefficient estimates can be found in Figure 4.

	$\tau = .1$	$\tau = .2$	$\tau = .3$	$\tau = .4$	$\tau = .5$	$\tau = .6$	$\tau = .7$	$\tau = .8$	$\tau = .9$
(Intercept)	0.0140	0.0345***	0.0366***	0.0342***	0.0312***	0.0334***	0.0355***	0.0076	−0.0240*
	(0.01)	(0.0072)	(0.0065)	(0.0072)	(0.0089)	(0.0098)	(0.0101)	(0.0157)	(0.0129)
ydep	−0.0263	−0.0495***	−0.0427***	−0.0174	0.0232	0.0462*	0.0525*	0.1239***	0.2439***
	(0.0183)	(0.0133)	(0.0162)	(0.0194)	(0.0249)	(0.0254)	(0.0289)	(0.0459)	(0.0308)
odep	−0.0139	−0.0362*	−0.025	−0.05**	−0.0934***	−0.1308***	−0.1517***	−0.1226***	−0.1281***
	(0.0235)	(0.0208)	(0.0165)	(0.0213)	(0.0239)	(0.0284)	(0.027)	(0.0301)	(0.0256)
money	0.0603***	0.0756***	0.0677***	0.0719***	0.0813***	0.101***	0.1437***	0.1825***	0.1848***
	(0.0139)	(0.0114)	(0.0112)	(0.0105)	(0.0145)	(0.0183)	(0.0192)	(0.0268)	(0.0173)
rgdppc	−0.0236	−0.1039***	−0.144***	−0.169***	−0.2549***	−0.3254***	−0.3233***	−0.3204***	−0.3054***
	(0.0319)	(0.0278)	(0.0179)	(0.0273)	(0.0363)	(0.0354)	(0.031)	(0.0494)	(0.0348)
ToT	−0.0019	−0.0048	0.002	0.0034	−0.0178	−0.0216	−0.0013	−0.0034	0.0069
	(0.0168)	(0.0073)	(0.0111)	(0.0111)	(0.0186)	(0.021)	(0.0159)	(0.0336)	(0.0278)
budbal	0.0174	0.0414*	0.0674**	0.0724***	0.0449	0.0142	0.0244	0.0943	0.0235
	(0.044)	(0.024)	(0.0284)	(0.0246)	(0.0286)	(0.0368)	(0.0335)	(0.0594)	(0.0457)
Pseudo-R^2	0.1203	0.1188	0.1328	0.1506	0.1765	0.2078	0.2426	0.2814	0.3266
Country Effects	Yes								
Time Effects	Yes								

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 5: OLS Quantile Regression Estimates

The results of the quantile regression largely reinforce the results of the linear regression models. Odep, ToT, and rgdppc are associated with negative inflation growth over the majority of their distributions while ydep and money are associated with positive inflation growth. The coefficient for budbal is predominantly positive, but just as with the regressions in Table 5, there is not enough evidence to claim the coefficients are non-zero values.

The coefficients for ydep and money show a strong trend of increasingly inflationary coefficient estimates with higher deciles. The lowest levels of the ydep ratio are associated with negative coefficient estimates until around the .3 decile (where ydep = 0.28) where coefficient estimates are indistinguishable from zero before becoming positive in the 0.6 decile (where ydep = 0.35) and beyond. With ydep, coefficient estimates appear to be taking on a non-linear form in relation to the decile distribution. This visualization can be misleading, however: a re-formatting of the x-axis shows that the relationship is linear with regard to units of ydep. This has been exemplified in Figure 3, where the relationship between the coefficient estimates and the underlying value are much more linear. All quantile coefficient estimates can be seen plotted in such a manner in Figures 10 and 11 in the appendix.

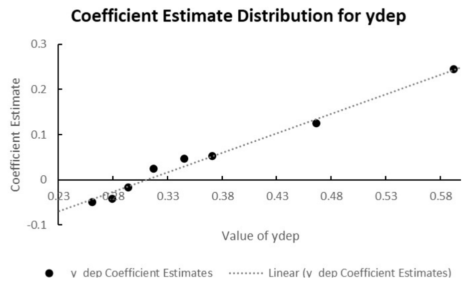


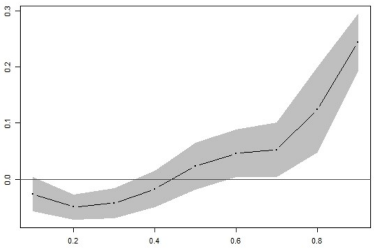
Figure 3: Quantile Regression Coefficients plotted against linear distribution of quantile values

Regardless of how coefficient estimates are plotted, there is a clear relationship where higher levels of youth dependency are associated with higher rates of annual inflation. Odep does not have such a clear relationship with inflation. There is no statistically significant relationship distinguishable from zero between the level of elderly dependency and annual changes in inflation until after the 0.3 decile (where odep=0.17). From the 0.3 deile, higher deciles of odep are associated with increasingly deflationary coefficient estimates until around the 0.7 decile (where odep=0.23) where the coefficient estimate stabilized to around 0.12. Although higher levels of old age dependency are generally associated with more negative inflation, the high standard errors inhibit the ability to draw a clear, authoritative conclusion at the lowest levels of the ratio (from the sample minimum of 0.13 to around 0.17). It appears as though there is a limit to the level at which increases in the old age dependency ratio are associated with lower levels of inflation growth, beginning at a odep ratio of around 0.23. Although the coefficient estimates suggest there is a reduction in the degree of deflation associated with the highest levels, large standard errors mean it is not possible to distinguish if the relationship is experiencing a trend reversal or a flattening.

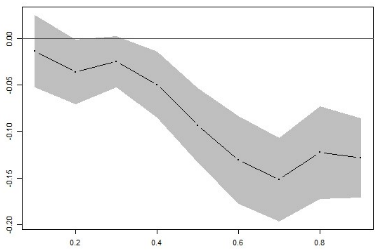
These results may indicate that the distributions of the demographic variables may behave very differently. While levels in the ydep ratio are almost monotonically associated with higher levels of inflation, there appears to be a point where further increases in the odep ratio stop being more deflationary at around the 0.20 level.

4.4 Smoothed Variable Regressions

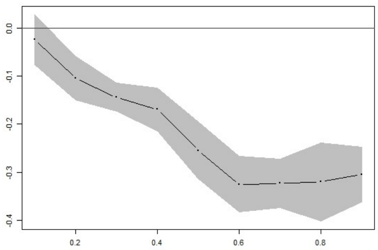
By limiting the bounds of the variance of variables without altering the underlying variance structure, regressions may more accurately be able to capture the underlying, long-run relationships in the data. In this section, the same regressions are conducted, but with two alterations. First, instead of using annual change in cpi, the cpi variable is replaced with an equally weighted moving



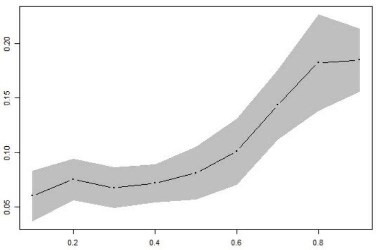
(a) ydep



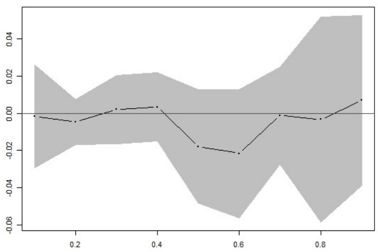
(b) odep



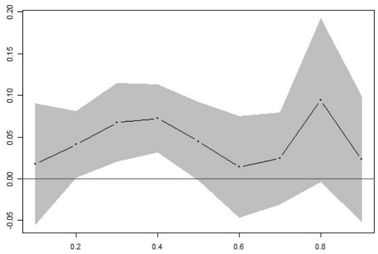
(c) rgdppc



(d) money



(e) ToT



(f) budbal

Figure 4: Regression Results of Table 5

average of three year's change in cpi ($MA_3(cpi_{i,t}) = \frac{1}{3}\Sigma_{i=0}^{2} cpi_{i,t-i}$). Second, the logs of elderly dependency ratio, $log(odep)$ and the youth dependency ratio, $log(ydep)$, will be used in the place of levels. These measures will aid in furthering the stationarity of the variables used in the regression, and more fundamentally define the long-run relationship between the rate of inflation and the degree of demographic dependency an economy is under.

To further investigate the impact of cross-sectional dependence, a pooled FGLS regression is added. Using the moving average of inflation and the logs of the dependency ratios, the regression formulas are re-defined.

The OLS model is re-defined as:

$$MA_3(cpi_{i,t}) = \mu + \mu_{0,i} + \beta_1 log(ydep)_{i,t} + \beta_2 log(odep)_{i,t} + \beta_3 money_{i,t} + \beta_4 rgppc_{i,t} + \beta_5 ToT_{i,t} + \beta_6 budbal_{i,t} + \varepsilon_{i,t} \tag{5}$$

The FE model is defined as:

$$MA_3(cpi_{i,t}) = \mu + \mu_{0,i} + \beta_1 log(ydep)_{i,t} + \beta_2 log(odep)_{i,t} + \beta_3 money_{i,t} + \beta_4 rgppc_{i,t} + \beta_5 ToT_{i,t} + \beta_6 budbal_{i,t} + \Sigma_{\forall i}\lambda_i d_i + \Sigma_{\forall t}\lambda_t d_t + \varepsilon_{i,t} \tag{6}$$

The FGLS model is re-defined as:

$$MA_3(cpi_{i,t}) = \mu_{0,i} + \beta_{FGLS} X_{i,t} + \varepsilon_{i,t} \tag{7}$$

Where: $X = [log(ydep_{i,t}), log(odep_{i,t}), money_{i,t}, rgppc_{i,t}, ToT_{i,t}, budbal_{i,t}]$

The FGLS-within model is re-defined as:

$$MA_3(cpi_{i,t}) = \mu_{0,i} + \beta_{FGLS} X'_{i,t} + \varepsilon_{i,t} \tag{8}$$

where $X' = [log(ydep)_{i,t}, log(odep)_{i,t}, money_{i,t}, rgppc_{i,t}, ToT_{i,t}, budbal_{i,t}, \Sigma_{\forall i} d_i, \Sigma_{\forall t} d_t]$

The sign and magnitude of coefficients are relatively consistent across the smoothed regressions and largely align with the results of the regressions of the last section. Aside from the FGLS-within equation, the r-squared values are higher, indicating that the included variables explain more of the variation in the 3-year moving average of inflation than they do the annual variation. The major exception being the old age dependency ratio, $log(odep)$. There is little agreement on the sign the old age dependency ratio should take on - this is the only instance where the pooled FGLS and FGLS-within models disagree on sign. Aside from pooled OLS, the regression models using within-estimation methods (FE & FGLS-within) find a negative sign, indicating that strong controls for individual effects are necessary for old age dependency to be associated with deflation.

The coefficient estimates for the demographic variables have become larger in magnitude at the mean. For a 1% increase in the youth dependency ratio, the 3-year average inflation rate is expected to rise by between 0.03% and 0.05%. With the average youth dependency ratio being 0.33 and the mean 3-year average inflation rate being 4.32% per annum, an increase in the youth dependency ratio by 0.0033 is associated with a 0.03% to 0.05% rise in the three year average for annual inflation. By extrapolating these values, a 0.10 increase in the youth dependency ratio is predicted to result in an increase of the average inflation rate by between 0.91% and 1.48%. This is larger than the range of between 0.87% and 1.04% predicted by the last set of regressions.

The same battery of regression tests of fit are conducted, the results of which can be found in Table 7. The smoothed regressions again show strong evidence for non-Gaussian distribution, heteroskedasticity, and serial correlation in the residual term.

A quantile regression is run to determine if the distribution-conditioned coefficient estimates change when the three year moving average term is used. The quantile regression takes the varible structure of Equation (5) with controls for country and time. The results of the regression can be found in Table 8 and graphically depicted in Figure 5.

Dep.Var: $MA_3(cpi_{i,t})$	OLS (5)	FE (6)	FGLS (7)	FGLS-within (8)
(Intercept)	0.0857^{**}		0.1026^{***}	
	(0.0354)		(0.0027)	
log(ydep)	0.0477^{***}	0.0319^{*}	0.0478^{***}	0.0299^{***}
	(0.0140)	(0.0172)	(0.0009)	(0.0026)
log(odep)	0.0049	−0.0040	0.0147^{***}	-0.0035^{***}
	(0.0129)	(0.0092)	(0.0012)	(0.0022)
money	0.2966^{***}	0.1609^{***}	0.3234^{***}	0.1599^{***}
	(0.0506)	(0.0404)	(0.0032)	(0.0018)
rgdppc	-0.4192^{***}	-0.3372^{***}	-0.3787^{***}	-0.3346^{***}
	(0.0672)	(0.0549)	(0.0033)	(0.0041)
ToT	−0.0580	−0.0295	-0.0610^{***}	-0.0298^{***}
	(0.0217)	(0.0216)	(0.0011)	(0.0010)
budbal	0.0384	0.0594	0.0540^{***}	0.0601^{***}
	(0.0524)	(0.0450)	(0.0037)	(0.0041)
Num. obs.	1176	1176	1176	1176
Country Effects	yes	yes	yes	yes
Time Effects	no	yes	no	yes
R^2	0.4019	0.5647	0.3544	0.0549
Adj. R^2	0.3890	0.5537		

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Standard errors for (5) and (6) are HAC robust standard errors

Table 6: Smoothed ydep and odep Ratio Results

	OLS (5)	FE (6)	FGLS (7)	FGLS-within (8)
Jaque-Bera Test for Normally Distributed Residuals				
X^2	364	364	468.48	5.4147
df	2	2	2	2
p	0.0000	0.0000	0.0000	0.06671
Studentized Breusch-Pagan Test for Homoskedastic Residuals				
BP	364.38	296.16	286.92	296.16
df	29	12	6	12
p	0.0000	0.0000	0.0000	0.0000
Durbin-Watson* Test for no auto-correlation in residuals				
DW	0.57048	0.57048	0.54124	0.34083
df	6	6	6	
p	0.0000	0.0000	0.0000	.62334
Breusch-Godfrey Test for no serial auto-correlation in residuals				
Chi^2	648.25	677.53	711.62	677.53
df	10	10	10	10
p	0.0000	0.0000	0.0000	0.0000

*modified BFN Panel Durbin-Watson Test for FGLS (7) and FGLS-Within(4)

Table 7: Tests for Smoothed Regression Fit

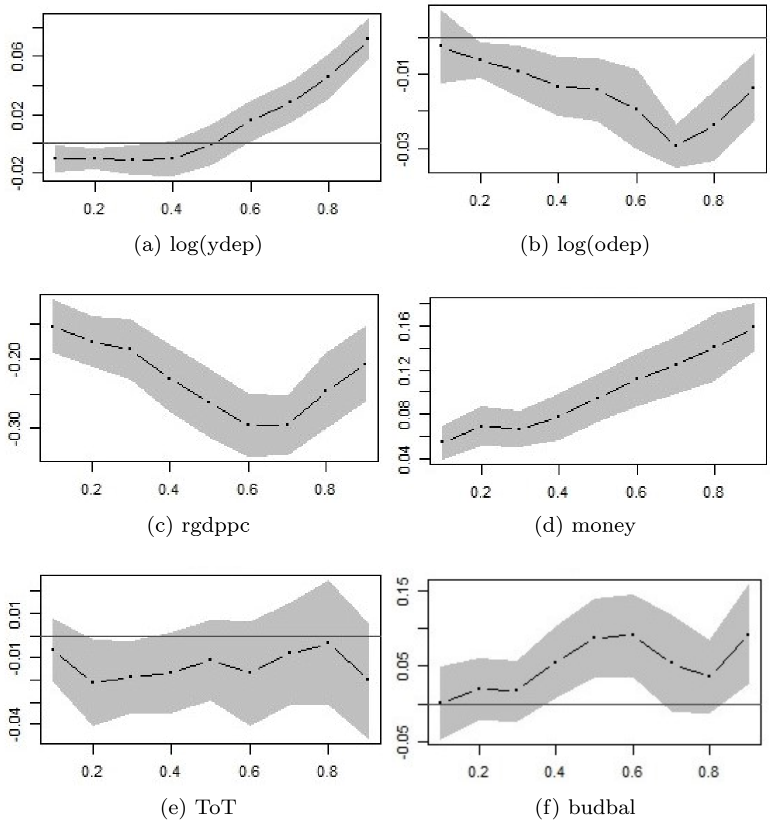
	$\tau = .1$	$\tau = .2$	$\tau = .3$	$\tau = .4$	$\tau = .5$	$\tau = .6$	$\tau = .7$	$\tau = .8$	$\tau = .9$
(Intercept)	-0.0087	-0.0054	-0.0092	-0.0143	-0.0027	0.008	0.0062	0.0399^{**}	0.0882^{***}
	(0.0147)	(0.0077)	(0.0116)	(0.0133)	(0.0145)	(0.0158)	(0.0119)	(0.0167)	(0.0171)
log(ydep)	-0.0106^{*}	-0.0107^{**}	-0.0117^{**}	-0.0104	-0.001	0.0159^{*}	0.0283^{***}	0.046^{***}	0.0717^{***}
	(0.0055)	(0.0042)	(0.0059)	(0.0071)	(0.0083)	(0.0084)	(0.008)	(0.0092)	(0.0083)
log(odep)	-0.0025	-0.0063^{**}	-0.0092^{**}	-0.0132^{***}	-0.014^{***}	-0.0194^{***}	-0.0294^{***}	-0.0237^{***}	-0.0136^{**}
	(0.0058)	(0.0028)	(0.0041)	(0.0047)	(0.0051)	(0.0064)	(0.0034)	(0.0056)	(0.0055)
money	0.0552^{***}	0.0695^{***}	0.0672^{***}	0.0782^{***}	0.0946^{***}	0.1118^{***}	0.1244^{***}	0.1403^{***}	0.158^{***}
	(0.0089)	(0.0102)	(0.0097)	(0.0123)	(0.0127)	(0.0141)	(0.0154)	(0.0178)	(0.0131)
rgdppc	-0.1529^{***}	-0.1752^{***}	-0.186^{***}	-0.2277^{***}	-0.2633^{***}	-0.295^{***}	-0.2963^{***}	-0.246^{***}	-0.2072^{***}
	(0.0231)	(0.0217)	(0.0259)	(0.0294)	(0.0293)	(0.0274)	(0.026)	(0.0333)	(0.0323)
ToT	-0.0068	-0.0214^{*}	-0.0189^{*}	-0.017	-0.0111	-0.0171	-0.0083	-0.0034	-0.0202
	(0.0085)	(0.0118)	(0.0098)	(0.0107)	(0.0109)	(0.0142)	(0.0139)	(0.0169)	(0.0158)
budbal	0.0014	0.0196	0.0171	0.055^{*}	0.0875^{***}	0.0909^{***}	0.0535	0.0358	0.0917^{**}
	(0.029)	(0.0243)	(0.0239)	(0.0284)	(0.0315)	(0.0329)	(0.0384)	(0.0289)	(0.0395)
Pseudo-R^2	0.3688	0.3718	0.3836	0.405	0.4343	0.4665	0.5048	0.5483	0.6017
Country Effects	Yes								
Time Effects	Yes								

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 8: OLS Quantile Regression Estimates with Smoothed Variables

The results of the quantile regression largely align with the results of the previous section - elderly dependency is generally deflationary up to a certain point, the level of youth dependency is positively correlated with the annual inflation rate, real gdp per capita growth is negatively correlated with the annual inflation rate, and increases in the money supply are positively correlated with inflation.

Taking the log of the youth dependency ratio appears to have linearized the previously quadratic relation of the coefficient estimates to the decile distribution, as would be expected. An increasing number of the lowest deciles are also associated with deflation in the youth dependency ratio. This may be the lack of cross-country heterogeneity with regard to ageing patterns over the sample period: countries with the lowest youth dependency ratios also have high elderly dependency ratios.



(a) log(ydep) (b) log(odep) (c) rgdppc (d) money (e) ToT (f) budbal

Figure 5: Regression Results of Table 8

4.5 Rate of Demographic Change

The level of demographic dependency is only one channel through which demographics may impact inflation. Another possible mechanism through which demography may impact inflation is through the rate of demographic change. Ageing populations are associated with changes in relative prices, savings habits, consumption patterns, and production capacity (Anderson et al., 2014). (D. E. Bloom, Canning, & Fink, 2010) note that developed countries, where healthcare expenditures already constitute significant portions of GDP, are more able to withstand the effects of ageing through behavioural, institutional, and policy flexibility. The effects of demographic shifts can be difficult to control, particularly if they are not well understood. If an economy is unprepared for a large demographic shift, there may be a point where institutions become unable to cope with the structural changes brought about by the magnitude of the demographic change. Although there has been ample econometric analysis conducted to determine the effects of ageing/youthing on an economy, there is limited empirical evidence analyzing the impact of the pace of a demographic shift has on an economy.

To analyze the rate of change's impact on economy-wide inflation, the regressions of the previous sections are augmented with variables for the rate of change of the demographic variable in the place of the level.

$$\Delta odep_{i,t} = odep_{i,t} - odep_{i,t-1}$$

$$\Delta ydep_{i,t} = ydep_{i,t} - ydep_{i,t-1}$$

$$\Delta log(ydep_{i,t}) = log(ydep_{i,t}) - log(ydep_{i,t-1}) = ln(\frac{ydep_{i,t}}{ydep_{i,t-1}})$$

$$\Delta log(odep_{i,t}) = log(odep_{i,t}) - log(odep_{i,t-1}) = ln(\frac{odep_{i,t}}{odep_{i,t-1}})$$

Using these manipulated variables, the equations of the prior sections can be reformulated to investigate the impact the pace of ageing has on inflation. The reformulation of the previous sections' regressions are outlined as follows:

The OLS model is defined as:

$$cpi_{i,t} = \mu + \beta_1 \Delta log(ydep_{i,t}) + \beta_2 \Delta log(odep_{i,t}) + \beta_3 money_{i,t} + \beta_4 rgppc_{i,t} + \beta_5 ToT_{i,t} + \beta_6 budbal_{i,t} + \varepsilon_{i,t} \tag{9}$$

The fixed effects (FE) model is defined as:

$$cpi_{i,t} = \beta_1 \Delta log(ydep_{i,t}) + \beta_2 \Delta log(odep_{i,t}) + \beta_3 money_{i,t} + \beta_4 rgppc_{i,t} + \beta_5 ToT_{i,t} + \beta_6 budbal_{i,t} + \Sigma_{\forall i} \lambda_i d_i + \Sigma_{\forall t} \lambda_t d_t + \varepsilon_{i,t} \tag{10}$$

The feasible generalized least squares (FGLS) model is defined as:

$$cpi_{i,t} = \mu + X_{i,t} \beta + \varepsilon_{i,t} \tag{11}$$

Where: $X = [\Delta ydep_{i,t}, \Delta odep_{i,t}, money_{i,t}, rgppc_{i,t}, ToT_{i,t}, budbal_{i,t}]$

The FGLS-within is model is created by applying a within transformation to (12):

$$cpi_{i,t} = X'_{i,t} \beta + \varepsilon_{i,t} \tag{12}$$

Where: $X' = [\Delta ydep_{i,t}, \Delta odep_{i,t}, money_{i,t}, rgppc_{i,t}, ToT_{i,t}, budbal_{i,t}, \Sigma_{\forall i} d_i, \Sigma_{\forall t} d_t]$

An additional set of regressions is conducted using smoothed dependant variables in order to confirm the findings of contemporaneous regressions.

The smoothed OLS model is defined as:

$$MA_3(cpi_{i,t}) = \mu + \beta_1 \Delta log(ydep_{i,t}) + \beta_2 \Delta log(odep_{i,t}) + \beta_3 money_{i,t} + \beta_4 rgppc_{i,t} + \beta_5 ToT_{i,t} + \beta_6 budbal_{i,t} + \varepsilon_{i,t} \tag{13}$$

The smoothed FE model is defined as:

$$MA_3(cpi_{i,t}) = \beta_1 \Delta log(ydep_{i,t}) + \beta_2 \Delta log(odep_{i,t}) + \beta_3 money_{i,t} + \beta_4 rgppc_{i,t} + \beta_5 ToT_{i,t} + \beta_6 budbal_{i,t} + \Sigma_{\forall i} \lambda_i d_i + \Sigma_{\forall t} \lambda_t d_t + \varepsilon_{i,t} \tag{14}$$

The smoothed FGLS-within model is defined as:

$$cpi_{i,t} = \mu + X''_{i,t} \beta + \varepsilon_{i,t} \tag{15}$$

Where: $X''_{i,t} = [\Delta log(ydep)_{i,t}, \Delta log(odep)_{i,t}, money_{i,t}, rgppc_{i,t}, ToT_{i,t}, budbal_{i,t}]$

The within transformation is applied to 15 achieved the FGLS-within model:

$$MA_3(cpi_{i,t}) = \beta_{FGLS} X'''_{i,t} + \varepsilon_{i,t} \tag{16}$$

Where: $X'''_{i,t} = [\Delta log(ydep)_{i,t}, \Delta log(odep)_{i,t}, money_{i,t}, rgppc_{i,t}, ToT_{i,t}, budbal_{i,t}, \Sigma_{\forall i} d_i, \Sigma_{\forall t} d_t]$

Dependant Variable	OLS (9) cpi	FE(10) cpi	FGLS(11) cpi	FGLS-within(12) cpi	OLS(13) $MA_3(cpi)$	FE(14) $MA_3(cpi)$	FGLS(15) $MA_3(cpi)$	FGLS-within(16) $MA_3(cpi)$
(Intercept)	0.0221^{*}		0.0232^{***}		0.0232^{***}		0.0202^{***}	
	(0.0088)		(0.001)		(0.0090)		(0.0000)	
Δ log(ydep)	-0.4107^{***}	-0.0206	-0.3821^{***}	-0.0198^{***}	-0.4763^{***}	-0.1001	-0.4465^{***}	-0.0946^{***}
	(0.1186)	(0.8273)	(0.0241)	(0.0028)	(0.1203)	(0.2833)	(0.0002)	(0.0097)
Δ log(odep)	-0.0837	-0.2889^{**}	-0.0740	-0.2911^{***}	-0.0143	-0.1290	-0.0431	-0.1313^{***}
	(0.1607)	(0.0402)	(0.0518)	(0.0060)	(0.1603)	(0.3363)	(0.7903)	(0.0109)
money	0.3288^{***}	0.1616^{***}	0.3138^{***}	0.1616^{***}	0.3182^{***}	0.1684^{***}	0.3282^{***}	0.1683^{***}
	(0.0549)	(0.0001)	(0.0077)	(0.0008)	(0.0537)	(0.0001)	(0.0000)	(0.0016)
rgdppc	-0.3008^{***}	-0.3238^{***}	-0.2970^{***}	-0.3236^{***}	-0.3215^{***}	-0.3425^{***}	-0.3205^{***}	-0.3409^{***}
	(0.0788)	(0.0000)	(0.0106)	(0.0011)	(0.0716)	(0.0000)	(0.0000)	(0.0033)
ToT	-0.0214	0.0076	-0.0161^{**}	0.0076^{***}	-0.0545^{**}	-0.0274	-0.0568^{**}	-0.0276^{***}
	(0.0335)	(0.8076)	(0.0057)	(0.0004)	(0.0262)	(0.2134)	(0.0341)	(0.0010)
budbal	0.0841	0.0437	0.0868^{***}	0.0948^{*}	0.0671	0.0671	0.0926	0.0674^{***}
	(0.0716)	(0.4997)	(0.0100)	(0.0009)	(0.0560)	(0.1299)	(0.1095)	(0.0028)
Num. obs.	1176	1176	1176	1176	1176	1176	1176	1176
Country Effects	yes	yes	yes	yes	yes	yes	yes	yes
Time Controls	no	yes	no	yes	no	yes	no	yes
R^2	0.3205	0.4860	0.3196	0.4665	0.3806	0.5593	0.3151	0.5343
Adj. R^2	0.3069	0.4730	0.2623		0.3682	0.5482	0.3116	

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Standard errors for (9), (10), (13), and (14) are HAC robust standard errors

Table 9: Rate of Demographic Change Results

	OLS (9)	FE (10)	FGLS (11)	FGLS-within (12)	OLS (13)	FE (14)	FGLS (15)	FGLS-within (16)
Dependant Variable	cpi	cpi	cpi	cpi	$MA_3(cpi)$	$MA_3(cpi)$	$MA_3(cpi)$	$MA_3(cpi)$
Jaque-Bera Test for Normally Distributed Residuals								
X^2	1671.5	1556.2	1607	529.32	469.11	441.31	688.2	759.35
df	2	2	2	2	2	2	2	2
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Studentized Breusch-Pagan Test for Homoskedastic Residuals								
BP	181.92	212.84	181.92	212.84	307.81	363.95	271.01	363.95
df	23	29	23	29	23	29	6	29
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Durbin-Watson* Test for no auto-correlation in residuals								
DW	0.9119	1.0271	0.7861	0.8964	0.5610	0.5849	0.5566	0.4127
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

*modified BFN Panel Durbin-Watson Test for FGLS(11), FGLS-within(12),FGLS(15), and FGLS-within(16)

Table 10: Tests for Pace of Ageing Regression Fit

The results of regressions (9) to (15) lack a clear interpretation. The OLS and FE regressions are unable to distinguish increases in the youth dependency ratio as having a non-zero impact on inflation. The FGLS and FGLS-within regressions find increases in the youth dependency ratio to have a negative and significant, at the 1% level, correlation with inflation, although there is strong disagreement as to the magnitude of the coefficient estimate. Controlling for time effects greatly reduces the coefficient estimates for Δ ydep and Δ odep. Increases in the old dependency ratio are also associated with deflation, but the variable's significance breaks down in the three year moving average of CPI when time effects and autocorrealation in the resiudals are not controlled for via FGLS. This may indicate there is a temporal disassociation between changes in the dependency ratios and their impact on cpi.

There are a number of dimensions that show changes in the youth dependency ratio and the elderly dependency ratios differ in the size and timing of their impact. The regressions using $MA_3(cpi)$ as the dependant variable have larger coefficient estimates for the impact of the youth dependency ratio's impact on inflation, but lower estimates for the impact of the old age dependency ratio. The impact of changes in the odep ratio are associated with more deflationary coefficient estimates than changes in the ydep ratio except when time effects are not controlled for. It is when time effects are not controlled for, however, that the impact of changes in the old age dependency ratio are not statistically significant. The regression indicates that changes in the odep ratio have a far larger impact than changes in the ydep ratio - this conclusions' universality is tempered, however, by the limited scope of demographic changes observed in the sample. There are very few ovservations of decreases in the elderly dependency ratio, and the largest observed fall in odep (-0.20%) is an order of magnitude smaller than the largest observed increase (2.46%).

The negative coefficients associated with increases in the dependency ratios can lead to multiple conclusions. The first being that the impact on inflation from changes in demographic variables are different from the impact of their levels. First year parents and first year retirees alike see changes in their consumption and lifestyle patterns - it may be that the initial impact of these pattern shifts are deflationary over an entire economy. The other possible result is that there is a misspecification causing spurious correlations. The youth dependency ratio plus the elderly dependency ratio equals the total dependency ratio of an economy. This further complicates the interpretation of the results, however, as (Broniatowska, 2019) and (Juselius & Takáts, 2015) find the level of the total dependency ratio to be strongly correlated with inflation, so increases in both dependency levels being associated with deflation deviates from what would be expected by the literature. Running the regressions with either $\Delta log(odep)$ or $\Delta log(ydep)$ does not change the sign or even the magnitude of coefficient estimates, indicating that the demographic estimates are consistent from each-other.

As a further robustness check, the three year moving averages of the youth and elderly dependency ratios were used in the regressions to control for spurious correlations due to short-run changes in the rate of demographic change. This alteration did not result in a significant change of the results.

The same battery of tests as were run in the previous regressions are run again, the results of which can be found in Table 10. Again, all models show strong evidence of heteroskedasticity, serial auto-correlation, and non-normality in the residual terms.

To further explore the relationship between the pace of ageing and inflation, regressions (9) and (13) are used in a quantile regression with country and time controls. The results of these regressions can be found in Table 11 and Table 12, respectively. Graphical depictions of the quantile regression coefficient estimates can be found in Figure 6 for (9) and Figure 7 for (13).

Dependant var: $cpi_{i,t}$	$\tau = .1$	$\tau = .2$	$\tau = .3$	$\tau = .4$	$\tau = .5$	$\tau = .6$	$\tau = .7$	$\tau = .8$	$\tau = .9$
(Intercept)	0.0037	0.0127^{***}	0.0163^{***}	0.0182^{***}	0.0217^{***}	0.0204^{***}	0.0209^{***}	0.0200^{***}	0.0258^{***}
	(0.0048)	(0.0035)	(0.0024)	(0.0021)	(0.0032)	(0.0027)	(0.0023)	(0.0039)	(0.0093)
$\Delta log(ydep)$	−0.0281	-0.0818^{*}	-0.0876^{*}	-0.1217^{**}	-0.1903^{***}	-0.1943^{***}	-0.183^{***}	−0.0676	0.1324^{*}
	(0.0481)	(0.045)	(0.0457)	(0.0473)	(0.05)	(0.0655)	(0.0686)	(0.0825)	(0.0873)
$\Delta log(odep)$	0.0325	−0.0683	−0.0329	−0.0431	−0.0707	−0.0583	−0.0201	−0.0752	-0.1923^{*}
	(0.0593)	(0.0547)	(0.0556)	(0.0548)	(0.0529)	(0.0746)	(0.0735)	(0.1112)	(0.1134)
money	0.0622^{***}	0.0766^{***}	0.0721^{***}	0.0711^{***}	0.0742^{***}	0.1185^{***}	0.1525^{***}	0.1977^{***}	0.2044^{***}
	(0.0124)	(0.0112)	(0.0095)	(0.01)	(0.0163)	(0.0216)	(0.0209)	(0.0288)	(0.0282)
rgdppc	−0.0188	-0.1143^{***}	-0.1471^{***}	-0.1747^{***}	-0.253^{***}	-0.3016^{***}	-0.3215^{***}	-0.2568^{***}	-0.2903^{***}
	(0.0318)	(0.0339)	(0.0243)	(0.0303)	(0.0366)	(0.0358)	(0.0401)	(0.052)	(0.0526)
ToT	−0.0091	0.0007	0.0036	0.0073	0.0023	−0.0088	−0.0001	−0.0216	0.0071
	(0.0124)	(0.0093)	(0.0073)	(0.0119)	(0.0154)	(0.0194)	(0.0175)	(0.0354)	(0.028)
budbal	0.0068	0.0492	0.0644^{**}	0.0727^{***}	0.0224	0.0337^{*}	0.0642	0.1593^{***}	0.0016
	(0.0439)	(0.0366)	(0.0281)	(0.0243)	(0.027)	(0.0198)	(0.0489)	(0.0497)	(0.0643)
Pseudo-R^2	0.2619	0.2781	0.2988	0.3210	0.3457	0.3764	0.4094	0.4396	0.4834
Country Effects	Yes								
Time Effects	Yes								

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 11: Pace Quantile Regression Estimates with 1-year change in CPI

Dependant var: $MA_3(cpi_{i,t})$	$\tau = .1$	$\tau = .2$	$\tau = .3$	$\tau = .4$	$\tau = .5$	$\tau = .6$	$\tau = .7$	$\tau = .8$	$\tau = .9$
(Intercept)	0.0063	0.018***	0.0182***	0.0177***	0.0164***	0.0175***	0.0152***	0.0223***	0.0289***
	(0.0038)	(0.0025)	(0.001)	(0.0021)	(0.0017)	(0.0017)	(0.0023)	(0.0031)	(0.0093)
$\Delta log(ydep)$	−0.139***	−0.0874**	−0.1364***	−0.105**	−0.1529***	−0.1361**	−0.1783***	0.013	0.2019***
	(0.0404)	(0.0414)	(0.0412)	(0.0458)	(0.0459)	(0.0607)	(0.0685)	(0.0797)	(0.0658)
$\Delta log(odep)$	0.024	0.0429	0.0807*	0.0845	0.1103***	0.069	−0.0167	−0.1871**	−0.2375***
	(0.0562)	(0.0407)	(0.0462)	(0.0585)	(0.04)	(0.0675)	(0.0755)	(0.08)	(0.0527)
money	0.0488***	0.074***	0.0705***	0.0968***	0.1203***	0.1314***	0.1612***	0.1852***	0.1532***
	(0.0094)	(0.0109)	(0.0104)	(0.0149)	(0.0124)	(0.0149)	(0.0202)	(0.0149)	(0.0141)
rgdppc	−0.1617***	−0.181***	−0.1805***	−0.2376***	−0.2755***	−0.2836***	−0.2682***	−0.2814***	−0.207***
	(0.0111)	(0.0212)	(0.0226)	(0.0276)	(0.0274)	(0.0286)	(0.0343)	(0.0455)	(0.0406)
ToT	−0.0015	−0.0241**	−0.0252**	−0.0102	−0.0162	−0.0074	−0.0126	−0.0174	−0.0274
	(0.0099)	(0.0113)	(0.0107)	(0.0115)	(0.0126)	(0.0158)	(0.0175)	(0.0234)	(0.023)
budbal	0.0092	0.0224	0.0392***	0.0549**	0.0781***	0.0832***	0.1097***	0.0728	0.0816**
	(0.0145)	(0.0211)	(0.0144)	(0.0248)	(0.0293)	(0.0171)	(0.0399)	(0.051)	(0.0386)
Pseudo-R^2	0.3712	0.3720	0.3850	0.4053	0.4340	0.4619	0.4946	0.5346	0.5902
Country Effects	Yes								
Time Effects	Yes								

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 12: Pace Quantile Regression Estimates with 3-year moving average change in CPI

In the graphics for the quantile regressions (Figures 6 and 5), a red vertical line is placed at the decile where where the change of the variable changes from negative to positive. The positioning of these vertical lines reveals how relatively uniform some aspects of economic and demographic change in the 19 countries that compose the panel data set were over the time being analyzed: less than 20% of the observed changes in the old age dependency ratio were negative and growth of the money supply has been by far and a way the rule rather than the exception.

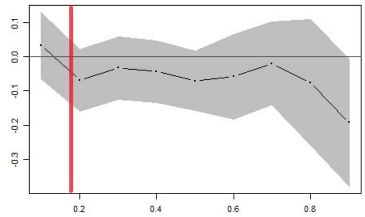
There are not enough observations to be able to draw any conclusions about the impact of a decrease in the elderly dependency ratio on inflation. Increases in the elderly dependency ratio appear to have a different impact depending on their magnitude: small changes are associated with immediate rises in inflation while large changes are associated with deflation.

The impact of increasing old age dependency may be a function of the preparedness of the state, the degree to which agents' habits change, and the magnitude at which agents are ageing in an economy. The exact form this function takes on is not clear and is an avenue for future research, but the nonlinear relationship between the magnitude of the increase in the elderly dependency ratio and inflation suggests there may be a truth to both the traditional and new views on the impact of ageing, in that ageing can be inflationary or deflationary conditional on the way retirements are financed and/or how prepared the economy is for the ageing of its workforce.

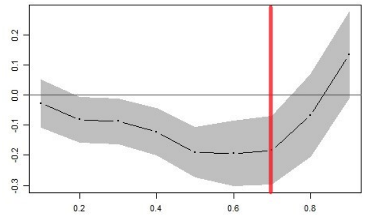
Alternatively, different parts of the population in the old-age dependant category may impact inflation differently. (Juselius & Takáts, 2015) find the impact of old age dependency to be ambiguous, but find evidence that the population aged 80+ are deflationary. The most rapidly ageing societies would be those that are increasing the 80+ share of the population the fastest, and may therefore be experiencing deflation while, in general, instantaneous increases in the old age ratio are slightly inflationary.

Changes in the youth dependency ratio react much like one would expect from the results of the regressions on the impact of levels: large increases in the youth dependency ratio are inflationary while declines are deflationary. What is interesting is that the size of the decline in the ydep ratio does not seem to change the negative impact. The observations of ydep ratio declines range from -2.7% in a year at the 0.1 quartile to 0% in the 0.6 quartile. The quartile regression does not find larger decreases in the ratio to be more deflationary - if anything, the larger the decrease in the ydep ratio, the more smaller the deflationary effect.

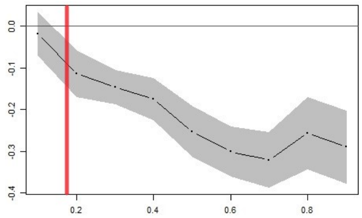
There is some cause for concern about misspecification, however, as the deciles where there is very little to no change in the ydep ratio (around the 0.7 decile) are associated with deflation. One would expect that no change in the ydep ratio to have no impact on inflation. A number of studies looking at capital flows have found markets are forward looking when it comes to demographic trends (Narciso, 2010; Poterba, 2004; Brooks, 2003). If that is the case, then changes in demographic variables should not be associated with changes in inflation as economic agents should have already been prepared for them. There do exist a number of possible explanations for why the coefficients for changes in dependency ratios are non-zero: the demographic changes may be unexpected due inaccurate expectations, there may be frictions preventing structural re-alignment in preparation for the demographic changes, or it may just be that economic agents ignore demographic changes because there are other concerns that will have a larger impact. So long as there are imperfect expectations or reactions to those expectations, a period with no change in demographic structure may therefore still be associated with a directional move in inflation if the expectations are consistently biased. Many population forecasts have underestimated the rate of population ageing over the previous 70 years (Katagiri et al., 2020; Beretta, Berkofsky, & Rugge, 2014). The addition of variables measuring the impact of demographic expectations against actual outcomes is left to future research.



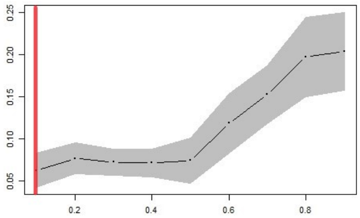
(a) Δ log(odep)



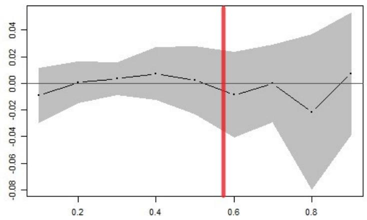
(b) Δ log(ydep)



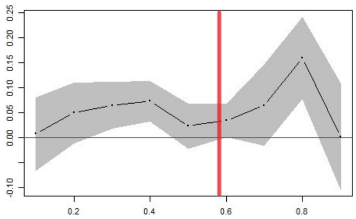
(c) rgdppc



(d) money

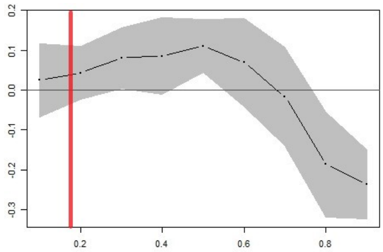


(e) ToT

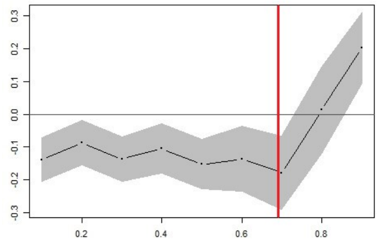


(f) budbal

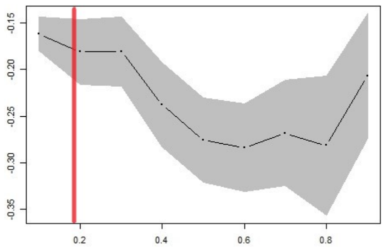
Figure 6: Regression Results of Table 11



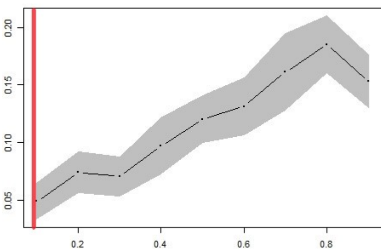
(a) Δ log(odep)



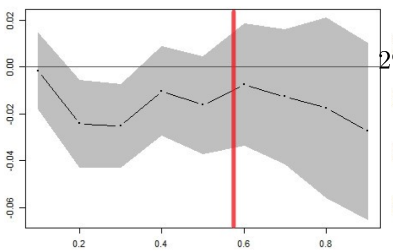
(b) Δ log(ydep)



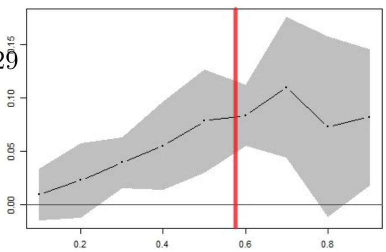
(c) rgdppc



(d) money



(e) ToT



(f) budbal

Figure 7: Regression Results of Table 12

4.6 Alternative Specification

The literature on demography and inflation has found a number of variables outside those used by (Broniatowska, 2019) and (Yoon et al., 2014) to be significant in accurately describing low-frequency inflation. This section will use different regression specifications to asses the relationship between dependency variables and inflation and to control for factors not include in previous sections.

In a 2015 speech, Chair of the Federal Reserve Janet Yellen provided a review of the Federal Reserve's considerations in understanding inflation and noted that core inflation can be largely described by a function of resource utilization, changes in import costs (particularly, the price of imported goods), and idiosyncratic shocks, while long run trend inflation is set by inflation expectations (Yellen, 2015). These determinants are used as inspiration for developing an augmented model of (Broniatowska, 2019)'s regressions in an attempt to more deeply refine the relationship between inflation and age structure.

To measure changes in recourse utilization the deviant labour force participation rate, measured as total employed workers relative to the prime age category (15-64) deviating from a HP-Filter trend($\lambda = 100$) , $lfpr$, is added. This variables aims to control for changes in labour utilization, and acts with changes in real gdp per capita, $rgdppc$, to measure variance in cpi attributable to recourse utilization in the economy.

Proponents of secular stagnation have argued that low population growth and increasing life expectancy are key determinants for the trend of declining real interest rates in ageing, developed economies (Hansen, 1938; Summers, 2014; Eggertsson and Mehrotra, 2014; Eichengreen, 2015; Aksoy et al, 2015). Further, (Anderson et al., 2014) found declines in population growth to be deflationary. (Katagiri et al., 2020) found that the impact ageing has on an economy is dependant on the cause of the ageing: increases in longevity are deflationary while declines in the birth rate are inflationary. The annual change in population growth, *pop*, and the annual change in life expectancy, $LifeExp$, and the annual change in mortality rate, *mortality*, are added to the alternative specification to control for these effects and as a proxy for real interest rates.

In controlling for inflation expectations, (Juselius & Takáts, 2018) find that demographic variables are able to explain large portions of trend inflation, indicating that the age structure of an economy may play a significant role in setting expectations for economic variables.

The regression equations can, similarly as to the previous sections, be divided into two categories: one set looking at the impact demographic levels have on inflation, and the other looking at the impact the contemporaneous rate of change of demographic variables on inflation.

4.6.1 Levels Specification

The OLS model is defined as:

$$\begin{aligned} cpi_{i,t} = \mu + \mu_{0,i} + \beta_1 log(ydep_{i,t}) + \beta_2 log(odep_{i,t}) + \beta_3 pop_{i,t} + \beta_4 LFPR_{i,t} + \beta_5 rgdppc_{i,t} + \\ \beta_5 money_{i,t} + \beta_6 ToT_{i,t} + \beta_7 ToT_{i,t} + \beta_6 budbal_{i,t} + \beta_7 LifeExp + \beta_8 Mortality + \varepsilon_{i,t} \end{aligned} \tag{17}$$

The FE model is defined as:

$$\begin{aligned} cpi_{i,t} = \beta_1 log(ydep_{i,t}) + \beta_2 log(odep_{i,t}) + \beta_3 pop_{i,t} + \beta_4 LFPR_{i,t} + \beta_5 rgdppc_{i,t} + \beta_5 money_{i,t} + \\ \beta_6 ToT_{i,t} + \beta_7 ToT_{i,t} + \beta_6 budbal_{i,t} + \beta_7 LifeExp + \beta_8 Mortality + \Sigma_{\forall i} \lambda_i d_i + \Sigma_{\forall t} \lambda_t d_t + \varepsilon_{i,t} \end{aligned} \tag{18}$$

The FGLS model is defined as:

$$cpi_{i,t} = \mu_{0,i} + \beta_{FGLS} X_{i,t} + \varepsilon_{i,t} \tag{19}$$

Were $X = [log(ydep)_{i,t}, log(odep)_{i,t}, pop_{i,t}, LFPR_{i,t}, rgdppc_{i,t}, money_{i,t}, ToT_{i,t}, ToT_{i,t}, budbal_{i,t}, LifeExp_{i,t}, Mortality_{i,t}]$

A within transformation applied to (19) yields the FGLS-within model:

$$cpi_{i,t} = \beta_{FGLS} X'_{i,t} + \varepsilon_{i,t} \tag{20}$$

Were $X = [log(ydep)_{i,t}, log(odep)_{i,t}, pop_{i,t}, LFPR_{i,t}, rgdppc_{i,t}, money_{i,t}, ToT_{i,t}, ToT_{i,t}, budbal_{i,t}, LifeExp_{i,t}, Mortality_{i,t}, \Sigma_{\forall i} d_i, \Sigma_{\forall t} d_t]$

4.6.2 Rate of Change Specification

The OLS model is specified as:

$$\begin{aligned} cpi_{i,t} = \mu + \mu_{0,i} + \beta_1 \Delta log(ydep_{i,t}) + \beta_2 \Delta log(odep_{i,t}) + \beta_3 pop_{i,t} + \beta_4 LFPR_{i,t} + \\ \beta_5 rgdppc_{i,t} + \beta_5 money_{i,t} + \beta_6 ToT_{i,t} + \beta_7 ToT_{i,t} + \beta_6 budbal_{i,t} + \beta_7 LifeExp_{i,t} + \\ \beta_8 Mortality_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{21}$$

The FE model is specified as:

$$\begin{aligned} cpi_{i,t} = \beta_1 \Delta log(ydep_{i,t}) + \beta_2 \Delta log(odep_{i,t}) + \beta_3 pop_{i,t} + \beta_4 LFPR_{i,t} + \beta_5 rgdppc_{i,t} + \\ \beta_5 money_{i,t} + \beta_6 ToT_{i,t} + \beta_7 ToT_{i,t} + \beta_6 budbal_{i,t} + \beta_7 LifeExp_{i,t} + \beta_8 Mortality_{i,t} + \\ \Sigma_{\forall i} \lambda_i d_i + \Sigma_{\forall t} \lambda_t d_t + \varepsilon_{i,t} \end{aligned} \tag{22}$$

The FGLS model is specified as:

$$cpi_{i,t} = \mu_{0,i} + \beta_{FGLS} X''_{i,t} + \varepsilon_{i,t} \tag{23}$$

$where X'' = [\Delta log(ydep)_{i,t}, \Delta log(odep)_{i,t}, pop_{i,t}, LFPR_{i,t}, rgdppc_{i,t}, money_{i,t}, ToT_{i,t}, ToT_{i,t}, budbal_{i,t}, LifeExp_{i,t}, Mortality_{i,t}]$

A within transformation applied to (23) yields the FGLS-within model:

$$cpi_{i,t} = \beta_{FGLS} X'''_{i,t} + \varepsilon_{i,t} \tag{24}$$

Where: $X''' = [\Delta log(ydep)_{i,t}, \Delta log(odep)_{i,t}, pop_{i,t}, LFPR_{i,t}, rgdppc_{i,t}, money_{i,t}, ToT_{i,t}, ToT_{i,t}, budbal_{i,t}, LifeExp_{i,t}, Mortality_{i,t}, \Sigma_{\forall i} d_i, \Sigma_{\forall t} d_t]$

Dependant Variable	OLS (17) cpi	FE (18) cpi	FGLS (19) cpi	FGLS-within (20) cpi	OLS (21) cpi	FE (22) cpi	FGLS (23) cpi	FGLS-within (24) cpi
(Intercept)	0.1111***		0.1154***		0.0061		0.0079***	
	(0.0362)		(0.0041)		(0.0127)		(0.0024)	
log(ydep)	0.0625***	0.0362**	0.0637***	0.036***				
	(0.0142)	(0.0178)	(0.0023)	(0.0032)				
log(odep)	0.0046	−0.0002	0.0060**	0.0002				
	(0.0155)	(0.0119)	(0.0019)	(0.0039)				
Δ log(ydep)					−0.5841***	−0.1609*	−0.5885***	−0.1575***
					(0.1280)	(0.0848)	(0.0200)	(0.0142)
Δ log(odep)					0.0681	−0.1465	0.1043**	−0.1098**
					(0.1679)	(0.1387)	(0.0367)	(0.0345)
Pop	−0.7524	0.7971	−0.7837***	0.7883* * *	1.0102	1.0857**	0.9651***	1.1068***
	(0.6444)	(0.5180)	(0.0740)	(0.0783)	(0.6167)	(0.4767)	(0.1004)	(0.0642)
LFPR	0.4780***	0.4527***	0.4908***	0.4425***	0.3944***	0.4372***	0.4363***	0.4277***
	(0.1003)	(0.0831)	(0.0108)	(0.0237)	(0.1135)	(0.0840)	(0.0265)	(0.0181)
rgdppc	−0.4071***	−0.3142***	−0.4072***	−0.3116***	−0.3211***	−0.3274***	−0.3274***	−0.3203***
	(0.0732)	(0.0599)	(0.0037)	(0.0058)	(0.0796)	(0.0620)	(0.0072)	(0.0066)
money	0.2919***	0.1349***	0.2915***	0.1330***	0.2946***	0.1348***	0.2889***	0.1324***
	(0.0507)	(0.0367)	(0.0027)	(0.0043)	(0.0522)	(0.0375)	(0.0042)	(0.0037)
ToT	−0.0234	0.0032	−0.0245***	0.0031	−0.0250	0.0057	−0.0268***	0.0052*
	(0.0311)	(0.0308)	(0.0016)	(0.0027)	(0.0328)	(0.0308)	(0.0045)	(0.0027)
budbal	0.0403	0.0366	0.0415***	0.0364***	0.0577	0.0366	0.0520***	0.0394***
	(0.0729)	(0.0679)	(0.0049)	(0.0076)	(0.0739)	(0.0670)	(0.0055)	(0.0066)
LifeExp	0.0097***	0.0022	0.0096***	0.0025***	0.0028	0.0019	0.0033***	0.0021***
	(0.0036)	(0.0033)	(0.0002)	(0.0003)	(0.0036)	(0.0033)	(0.0004)	(0.0003)
Mortality	0.0010	−0.0001	0.0010***	−0.0001***	−0.0008	−0.0003	−0.0008***	−0.0003***
	(0.0007)	(0.0005)	(0.0000)	(0.0000)	(0.0008)	(0.0005)	(0.0000)	(0.0000)
Num. obs.	1176	1176	1176	1176	1176	1176	1176	1176
Country Effects	yes	yes	yes	yes	yes	yes	yes	yes
Time Effects	no	yes	no	yes	no	yes	no	yes
R^2	0.3752	0.5131	0.3751	0.53099	0.3424	0.5102	0.34184	0.4914
Adj. R^2	0.3606	0.4991			0.3269	0.4960		

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Standard errors for (17), (18), (21), and (22) are HAC robust standard errors

Table 13: Regression Results for Alternate Specification

4.6.3 Results

The coefficient estimates under the alternative specification are largely consistent with the estimates of prior models. Compared to the estimates presented in Table 7 the estimated signs, magnitudes, and statistical significance of variables are very similar. All else equal, given a 1% increase in the youth dependency ratio the increase in cpi is expected to be between 0.030% to 0.048% in Table 7 and 0.036% to 0.061% using the alternative specification, with all log(ydep) coefficient estimates being significant at the 10% level or better.

The level estimates for the old age dependency ratio are more likely to be indistinguishable from zero than under the regressions of Table 7. No model finds the variable to be statistically significantly correlated with changes in cpi. This largely matches with the results observed in previous regression estimates.

For the auxiliary variables in the levels regressions, the coefficient estimates for changes in population, life expectancy, and mortality, are mostly statistically indifferentiable from zero except in the FGLS and FGLS-within regressions but the scale of the coefficient estimates are approximately similar regardless of regression technique. Increases in population are associated with inflation which aligns with the literature. Increases in life expectancy, however, are associated with inflation which is counter to the predictions of (Katagiri et al., 2014). LFPR, which measures the labour force participation rate's deviation from trend is positively associated with inflation, as expected. A 1% increase in the prime labour force participation rate from trend is associated with a 0.44% to 0.47% increase in the annual inflation rate.

For the rate of change regressions (21) to (23) the signs for all variables are consistent with previous rate of change regression estimates regarding sign for the demographic variables, but estimates vary wildly with regards to magnitude. The coefficient estimates for Δ log(ydep) are 8 times larger using the alternative specification than with the regressions on cpi in Table 11 and the estimates for Δ log(odep) are two times their counterpart. However, the rate of change coefficients are the much more similar to their past equivalents when regressed against $MA_3(cpi)$. The introduction of additional control variables appears to be having the same effect as using a smoothed dependant variable for the demographic variables.

Dependant var: $cpi_{i,t}$	$\tau = .1$	$\tau = .2$	$\tau = .3$	$\tau = .4$	$\tau = .5$	$\tau = .6$	$\tau = .7$	$\tau = .8$	$\tau = .9$
(Intercept)	0.0079	0.0061	0.0026	−0.0017	−0.0101	0.02	0.0145	0.0601***	0.0621***
	(0.0157)	(0.0068)	(0.0117)	(0.0153)	(0.0154)	(0.0171)	(0.0184)	(0.018)	(0.0147)
log(ydep)	−0.0045	−0.0047	−0.0043	0.0047	0.0057	0.0289***	0.0303***	0.0575***	0.0607***
	(0.0072)	(0.0031)	(0.0062)	(0.0075)	(0.0083)	(0.0091)	(0.0105)	(0.0118)	(0.0092)
log(odep)	0.0085	0.0021	−0.0055	−0.017***	−0.0221***	−0.0237***	−0.027***	−0.016**	−0.0159***
	(0.0066)	(0.0026)	(0.0049)	(0.0065)	(0.0059)	(0.0067)	(0.0066)	(0.0064)	(0.0049)
pop	0.416*	0.2898***	0.067	−0.1199	−0.0544	−0.1	−0.0585	0.3577	0.8582***
	(0.2177)	(0.0986)	(0.1407)	(0.1647)	(0.2072)	(0.1998)	(0.239)	(0.3407)	(0.3172)
LFPR	0.4128***	0.4034***	0.3554***	0.3693***	0.3884***	0.4041***	0.3564***	0.468***	0.5534***
	(0.0548)	(0.0409)	(0.0392)	(0.0425)	(0.0507)	(0.059)	(0.0587)	(0.0753)	(0.0681)
rgdppc	−0.0459	−0.0765***	−0.1379***	−0.1973***	−0.2397***	−0.3008***	−0.3224***	−0.3394***	−0.2791***
	(0.0293)	(0.026)	(0.0255)	(0.0353)	(0.0328)	(0.036)	(0.0221)	(0.0442)	(0.0326)
money	0.0631***	0.0466***	0.0513***	0.0614***	0.068***	0.0783***	0.1138***	0.1301***	0.1403***
	(0.0102)	(0.0116)	(0.0094)	(0.0123)	(0.0132)	(0.014)	(0.0169)	(0.0213)	(0.0204)
ToT	−0.0058	−0.0053	0.0073	0.0038	−0.0094	−0.0176	−0.0084	−0.0082	0.0288
	(0.0181)	(0.0119)	(0.0158)	(0.0114)	(0.0109)	(0.0174)	(0.0206)	(0.0228)	(0.0278)
budbal	0.0261	0.0087	0.0143	0.0434*	0.0301	0.0426	0.055	0.0576	0.0541
	(0.0401)	(0.0274)	(0.0268)	(0.0225)	(0.0299)	(0.0396)	(0.0431)	(0.0528)	(0.0505)
LifeExp	−0.0027	−0.0034**	−0.0012	−0.0011	0.001	0.0029	0.0078**	0.0117***	0.0045
	(0.0023)	(0.0015)	(0.0018)	(0.0023)	(0.0027)	(0.0033)	(0.0037)	(0.0041)	(0.0046)
MortalityRate	0.0001	0.0001	0.0002	0.0003	−0.0001	0.001	−0.0003	−0.0008	−0.0002
	(0.0002)	(0.0002)	(0.0004)	(0.0006)	(0.0006)	(0.0008)	(0.001)	(0.0011)	(0.0016)
Pseudo-R^2	0.2865	0.2976	0.3134	.3327	0.3608	0.3939	0.4308	0.4637	0.5147
Country Effects	Yes								
Time Effects	Yes								

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 14: Alternate Specification Quantile Regression Estimates - Levels

Dependant var: $cpi_{i,t}$	$\tau = .1$	$\tau = .2$	$\tau = .3$	$\tau = .4$	$\tau = .5$	$\tau = .6$	$\tau = .7$	$\tau = .8$	$\tau = .9$
(Intercept)	−0.0024	0.0054	0.0136***	0.0175***	0.0141***	0.0127***	0.0058***	0.0019	0.0084
	(0.0054)	(0.0036)	(0.0036)	(0.0032)	(0.0031)	(0.0034)	(0.0051)	(0.0071)	(0.0081)
Δ log(ydep)	−0.1248**	−0.1515***	−0.1549***	−0.1858***	−0.2001***	−0.2099***	−0.2009***	−0.1099	−0.0005
	(0.0575)	(0.0401)	(0.0451)	(0.0457)	(0.0608)	(0.0566)	(0.0771)	(0.0851)	(0.0983)
Δ log(odep)	0.0965	0.0865*	0.0477	−0.0411	−0.0003	−0.022	0.0587	−0.0102	−0.1209
	(0.0799)	(0.0488)	(0.0563)	(0.0585)	(0.0662)	(0.0736)	(0.0858)	(0.1128)	(0.0814)
pop	0.4074**	0.4537***	0.2599*	0.0205	0.3074	0.4919***	0.9464***	1.1632***	2.0602***
	(0.1951)	(0.1545)	(0.1379)	(0.1648)	(0.2009)	(0.1837)	(0.2809)	(0.3554)	(0.2922)
LFPR	0.407***	0.4019***	0.3952***	0.3616***	0.3816***	0.3683***	0.3471***	0.4244***	0.5159***
	(0.025)	(0.03)	(0.0237)	(0.0288)	(0.0378)	(0.0388)	(0.0397)	(0.0536)	(0.0454)
rgdppc	−0.0662***	−0.1177***	−0.1528***	−0.1982***	−0.2455***	−0.3134***	−0.3171***	−0.3219***	−0.2951***
	(0.0623)	(0.0589)	(0.0355)	(0.0418)	(0.0545)	(0.0558)	(0.0648)	(0.0852)	(0.0852)
money	0.0606***	0.0517***	0.0468***	0.0657***	0.0733***	0.0967***	0.1071***	0.1486***	0.1289***
	(0.0161)	(0.0106)	(0.0112)	(0.0103)	(0.0147)	(0.0198)	(0.0211)	(0.0226)	(0.025)
ToT	−0.0098	0.0004	0.009	0.0058	−0.0123	−0.0196	−0.0028	0.0028	0.0243
	(0.0196)	(0.0125)	(0.014)	(0.0108)	(0.013)	(0.0165)	(0.0195)	(0.0234)	(0.035)
budbal	−0.01	0.0315	−0.0003	0.0487*	0.0569*	0.0189	0.0379	0.0595	0.039
	(0.0411)	(0.0338)	(0.0278)	(0.0274)	(0.0309)	(0.0366)	(0.0407)	(0.0546)	(0.0619)
LifeExp	−0.0036*	−0.004**	−0.0025	−0.0006	0.0022	0.0004	0.0071*	0.0142***	0.0072
	(0.0022)	(0.0018)	(0.0022)	(0.0025)	(0.0028)	(0.0032)	(0.0042)	(0.0052)	(0.0053)
Mortality	0.0001	−0.0001	0.0002	−0.0005	0.0001	−0.0009	−0.0016	−0.003**	−0.0022
	(0.0002)	(0.0002)	(0.0004)	(0.0004)	(0.0003)	(0.0006)	(0.0011)	(0.0014)	(0.0018)
Pseudo-R^2	0.2872	0.3002	0.3161	0.3344	0.3583	0.3883	0.4224	0.4565	0.5083
Country Effects	Yes								
Time Effects	Yes								

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 15: Alternate Specification Quantile Regression Estimates - Rate of Change

4.7 Alternative Specification - Quantile Regression

4.7.1 Levels

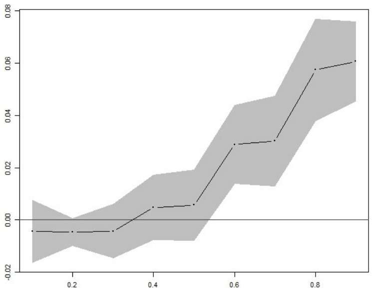
The coefficient estimates for the alternative regression in demographic levels largely align with prior regressions' results in coefficient sign and in the shape the coefficient estimates take on when plotted against their decile distribution. The coefficient distributions for log(odep) and log(ydep) are very similar in structure and magnitude, showing that the additional control variables do not result in a deterioration of the dynamics noted in earlier quantile regressions.

Beyond approximately the median ydep observation (0.32), further increases in the ydep ratio are associated with higher rates of annual inflation. The increasing nature of the relationship beyond the median observation is slightly more jagged under the alternative specification, but still monotonically increasing. The lowest levels of the ydep ratio are associated with deflation, as they are under the smoothed specification outlined in Table 7, but the coefficient estimates are not statistically differentiable from zero. Therefore, although there is not a discernibly non-zero impact for ydep ratios below around 0.32, the alternative specification reinforces the monotonically positive and increasing relationship between ydep level above the median and annual inflation.

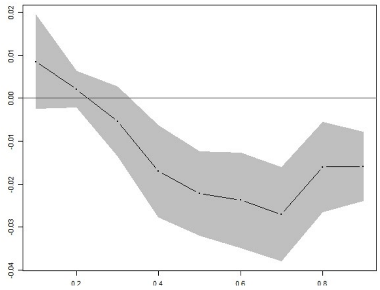
The findings for the level of the odep ratio are again reinforced as observations of odep beyond the third decile (where odep equals 0.17) are associated with deflation, but that the marginal increase in deflation associated with higher levels of the odep ratio flattens and even begins reversing around the 0.7 decile. Under the alternative specification, the coefficient estimates of deciles 0.1 to 0.3 are not statistically distinguishable from zero whereas that was the case only in decile 0.1 for the quartile regression results outlined in Table 7.

The results associated with the auxiliary variables are also largely similar under the alternative specification. The 0.9 quartile estimate for rgdppc shifts direction from the trend of the previous series of deciles which follow a monotonically decreasing trend. Although this may be due to low statistical power at the tails of the distribution, it mirrors an upward trend in the right end of the distribution that can also be seen in tile (c) of Image 5 where the direction change begins two deciles sooner (decile 0.7 where real gdp per capita growth is 3.54% compared to 5.50% at the 0.9 quartile). It may be that, although real gdp per capita growth is generally deflationary, the most extreme gdp per capita increases require economies that are running so "hot" that there is less of a clear-cut deflationary effect at those levels. Budbal, national budget balance as a percent of GDP, generally continues to be associated with a positive coefficient, but not distinguishable from zero. ToT, similarly, is generally associated with a negative coefficient that is not statistically distinguishable from zero.

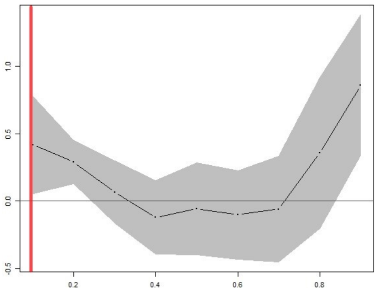
The other demographic variables - population growth rate, life expectancy, and youth mortality, behave differently from how they were expected to. The lowest and highest deciles of population growth are associated with zero, with the coefficient becoming indistinguishable from zero between the 0.3 to 0.8 quartile (where the changes in population are 0.384% and 1.12%, respectively). The trend that began to form towards the lower deciles appears to go against the findings of (Anderson et al., 2014), but there are no observations in the sample period where negative population growth were negative to be able to truly compare. Increases in life expectancy appear to be inflationary from deciles 0.5 to 0.9 (where increases range from 0.1 years to 0.4 years). The findings of the alternative specification appear to show that low, positive population growth and increasing life expectancy are associated with positive inflation. This finding is puzzling and contradictory of the literature as, else equal, larger increases in the cpi would imply a higher real interest rate. Most studies analyzing the impacts of demographic variables on interest rates have used VAR models or models with lagged dependant variables, and thus the specification chosen here may not be fully representative of the change in demographic variables' impact on longer run inflation. Using the 3-year moving average



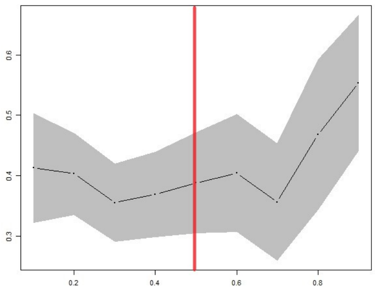
(a) log(ydep)



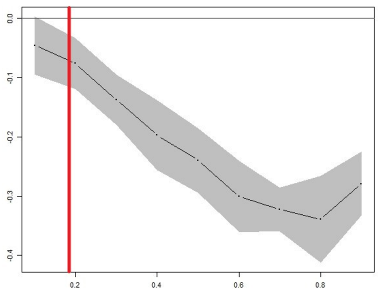
(b) log(odep)



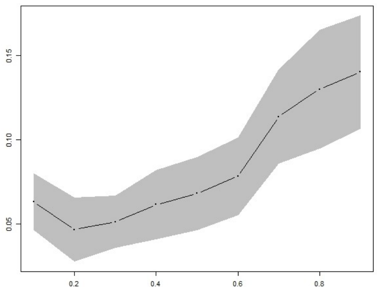
(c) pop



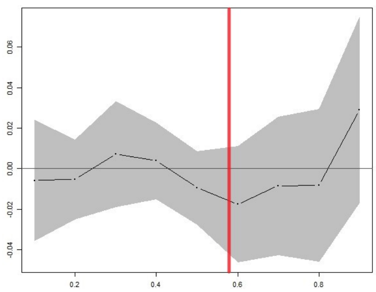
(d) PrimeLFPR



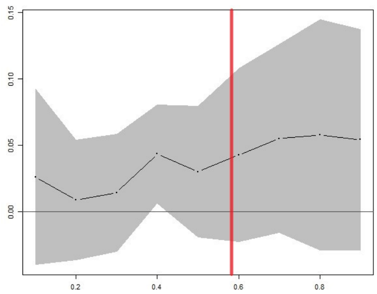
(e) rgdppc



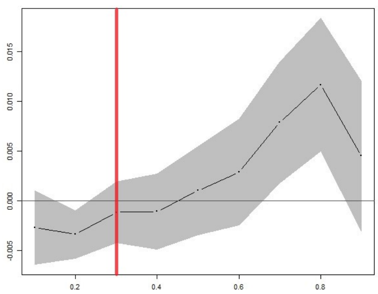
(f) money



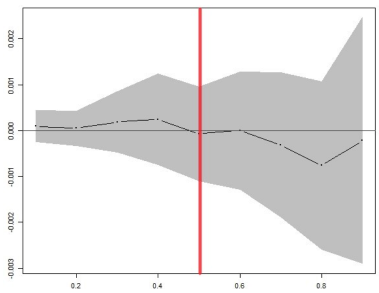
(g) ToT



(h) budbal

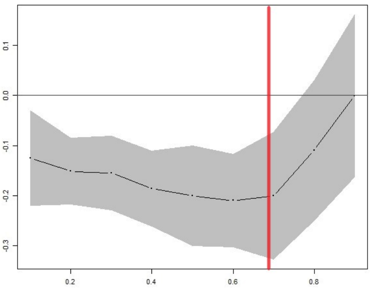


(i) LifeExp

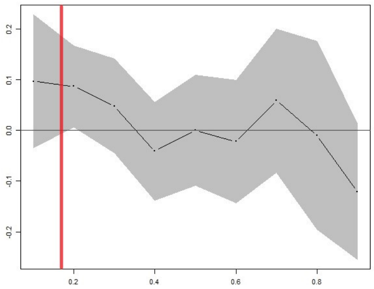


(j) Mortality

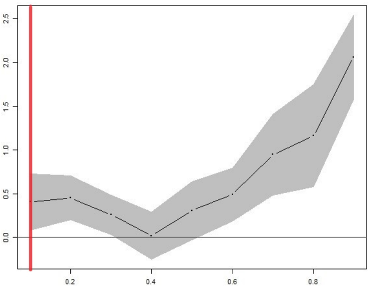
Figure 8: Regression Results of Table 14



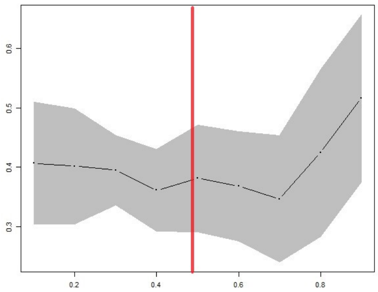
(a) Δ log(ydep)



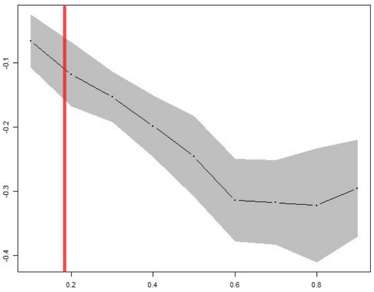
(b) Δ log(odep)



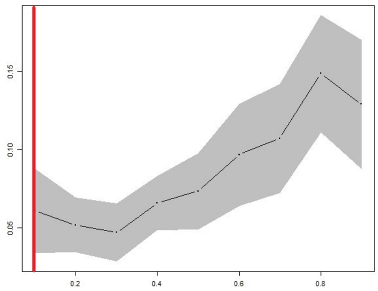
(c) pop



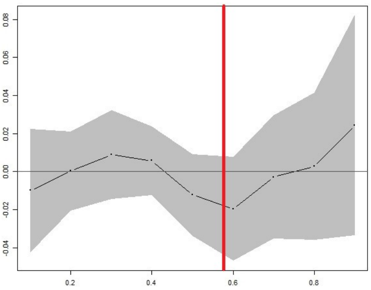
(d) PrimeLFPR



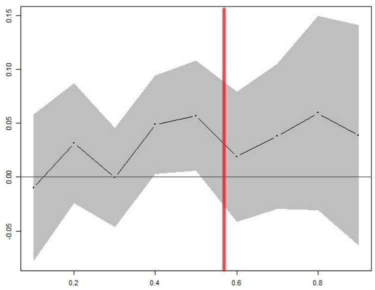
(e) rgdppc



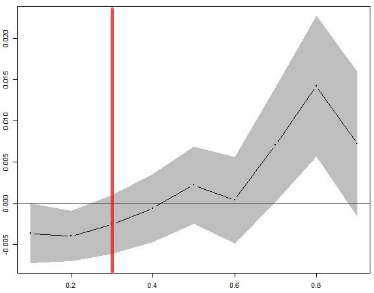
(f) money



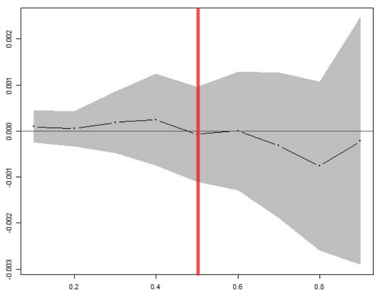
(g) ToT



(h) budbal



(i) LifeExp



(j) Mortality

Figure 9: Regression Results of Table 15

of changes in cpi in the place of contemporaneous changes in cpi does not significantly alter these relationships, thus for the short-term focus of this paper the results of the previous sections appear to be consistent.

4.7.2 Rate of Change

As with the non-quantile regressions, the results of the rate of change regressions under the alternate specification generally more closely mirror the results attainded by using a 3-year moving average of the changes in cpi. The alternative specification reinforces the patters observed for the dependency ratios. In the youth dependency ratio, decreases are generally associated with deflation while increases are increasingly associated with inflation. At the 0.9 decile (where ydep increases at 1% per year), the coefficient estimate is not statistically differentiable from zero, as was the case under the quartile regressions in Tables 11 and 8. The pattern observed in both those tables that larger decreases in the youth dependency ratio are less deflationary is again seen in the alternative specification.

The trends observed in prior regressions regarding changes in the elderly dependency ratio are seen again under the alternative specification, albeit with much larger standard errors. The general trend observed in Table 8 that small increases in the old age dependency ratio are inflationary while only increases beyond around the 0.7 quartile (where Δ log(odep) is around 1.7% per year) or greater are deflationary is generally reinforced by coefficient estimates, but there is not sufficient evidence to statistically differentiate the coefficients from zero.

The change in variables measuring demographic structure change the pattern associated with pop: a larger proportion of deciles associated with increases in population are significantly correlated with increases in inflation. There is again a point at the 0.4 decile that is statistically undifferentiable from zero, but from the 0.6 to the 0.9 decile, the positive coefficients are statistically significant at the 1% level. This reinforces the puzzling finding of the level regressions that both the smallest observed increases and the largest observed increases in population are associated with inflation, but the observations in between (0.49% to approximately 1% population growth in a year) are not.

5 Conclusion

This paper began with a re-creation of the regression models used by (Broniatowska, 2019) and (Yoon et al., 2014) to analyze demography's impact on inflation through the use of dependency ratios. Using a panel data set of 19 advanced economies from 1950 - 2017, this paper largely confirms the results of those earlier papers in finding that increases in the youth dependency ratio are associated with increases in inflation while increases in the old age dependency ratio are associated with deflation. The use of quantile regressions provides the insight that coefficient estimates for the demographic association to inflation differ across the observed distribution of dependency ratios, and that there may be nonlinear aspects in the relationship between age structure and inflation in an economy.

Youth dependency ratios above 0.32 are associated with positive coefficient estimates that grow larger as the ydep ratio rises. Youth dependency ratios below that level are generally associated with coefficients of zero or lower. The relationship between the coefficient estimate and the level of the youth dependency ratio above the 0.32 threshold is monotonically positive and linear: higher levels of the youth dependency ratio are associated with higher annual inflation rates.

Evidence of a nonlinear effect are also found for old age dependency ratios - above 0.17 there is an association with deflation. Higher elderly dependency ratio levels are associated with higher levels of deflation up to around 0.23. After that point, marginal increases in the odep ratio are not associated with rising rates of deflation - rather, coefficient estimates stabilize.

By replacing demographic dependency levels with their rates of change, the regressions were modified to analyze how the speed of the demographic transition impacts inflation. Decreases in the youth dependency ratio were found to be deflationary. There is some evidence that large decreases in the youth dependency ratio have a "dampened" coefficient estimate: the larger the decrease, the less deflationary the decrease. There is mixed evidence that very large increases in the youth dependency ratio are inflationary. There is little evidence that changes in the old age dependency ratio are contemporaneously correlated with changes in inflation. At the extreme ends of the observed changes in the elderly dependency ratio, there is some evidence that the top 10% of odep increases are slightly deflationary (a 2.5% increase in the old age dependency ratio in a year is associated with -0.1% change in the annual inflation rate).

Lastly, an alternative regression specification is devised using additional variables that have been found to play important roles as channels through which demography impacts inflation (population growth, life expectancy, and mortality rate). The regression results were found to be robust to these additional controls, including the coefficient distributions found using the quantile regressions.

The use of quantile regressions provides a new lens through which to analyze demography's impact on economic variables. The distribution of dependency variables is found to expose a less than straightforward relationship between demography and inflation. The use of nonlinear and non-parametric techniques in estimating the relationship between demography and economics across the distribution of variable values and time may prove useful insights for policymakers in fine tuning their approach to tackling the problems of their nations. The increasing trend in coefficient estimates for high ydep ratios may provide some additional insights into how the demographic dividend pays out: as the young age dependency ratio falls in a society, every marginal decrease in the ratio becomes an increasingly deflationary change. This finding may help to explain why the decreases in youth dependency ratios, even in the developed world, have been so strongly associated with declines in the real interest rate - the deflationary impacts of the demographic trends were nonlinear in their impact. The negative bound on coefficient estimates associated with the elderly dependency ratio provide a equally useful insight that increases in the old age dependency have nonlinear impacts on inflation until a certain point, after which marginal increases in the old age dependency ratio are associated with linear expected declines in the annual inflation rate.

6 Limitations and Future Research

6.1 Limitations

The most significant limitation of this paper is the scope of the sample. The economies analyzed in this paper are all developed economies with a shared experience of positive population growth, increasing elderly dependency ratios and falling youth dependency ratios over the period being analyzed. The results of this paper are thus largely driven by the variation in demographic ratios between similar countries over time, and thus may not be representative in developing economies or youthing economies where the youth dependency ratio is rising as the old age dependency ratio falls. This is a particularly important limitation as these demographic trends observed over the last half century will evolve into decreasing populations with high and stable elderly dependency ratios over the coming century. Extremely high dependency ratios or changes in economic structures to cope with these changes mean that there is no guarantee that the results found in this paper will be applicable in the future.

There are also no controls in place for institutional quality. (Narciso, 2010) does not find institutional quality to be a statistically significant determinant in the relation between demography's impact on capital flows, but this does not necessarily exclude their role in determining how demography is able to impact inflation. The sample used in this paper is of developed, relatively liberal economies - this sample thus implicitly assumed that demographic changes enter into the economy through market channels, but this is in no way controlled for. As noted throughout this paper, there a number of ways governmental institutions could impact this channel - this thus remains an interesting consideration for future investigations on the intersection of demographics and economics.

The use of dependency ratios rather than population polynomials has also limited how much of the population structure has been incorporated into the analysis. Other papers in the literature, such as (Juselius & Takáts, 2018) and (Higgins & Williamson, 1996) use population polynomials to incorporate the entire population structure into their analysis. This paper has opted to use demographic dependency ratios for the ease and accessibility of understanding in regression results, particularly in the context of quantile regressions.

6.2 Future Research

This paper has found strong evidence for non-linearity in the relationship between age structure and inflation, both in terms of levels and rates of change. More research is needed to confirm the existence of the non-linearity of demography's impact in an economy, and the extent to which this non-linearity exists for other economic variables. This paper was unfortunately not able to explore the particulars of demography's non-linearity and leaves this aspect of research to future endeavours.

Few papers in the literature using dependency ratios take into account how changing labour force patters affect the impact ageing has on economic variables. The average years of schooling and average age of retirement have changed significantly over the previous century, but it is still uncertain as to the effect these changes have had on the impact different age groups have on inflation.

The extent to which demographic patterns affect economic variables is incredibly important to understand in as detailed a manner as possible. Most developed economies to one degree or another, and many developing economies, are facing a wave of retirement as generations born in the later half of the 20th century age out of prime working age without a replacement generation of equal or greater size. Many developing economies are currently experiencing or are at the tail end of the generational structure that results in a demographic dividend. The extent to which policymakers understand their control over the fruits or burdens demographic structures create, and how exactly these structures will come to impact economies, will be of vital importance as the world continues through what will likely be one of the most challenging demographic transitions to date.

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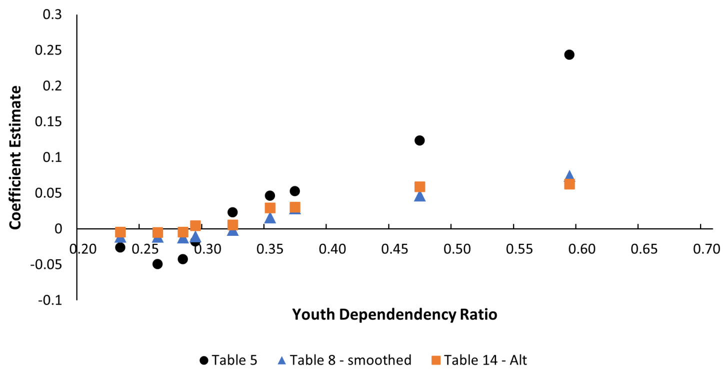
8 Appendix

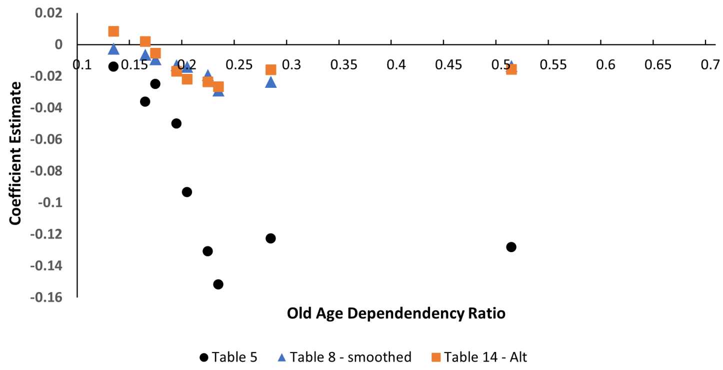
Quantile	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1
cpi	0.0053	0.0131	0.0186	0.0234	0.0293	0.0374	0.0485	0.0972	0.3212
ydep	0.2296	0.2608	0.2787	0.2936	0.3166	0.345	0.371	0.4665	0.5924
odep	0.1342	0.1568	0.173	0.1853	0.1985	0.2156	0.2305	0.2771	0.5057
log(ydep)	-1.4713	-1.3441	-1.2778	-1.2254	-1.1502	-1.0641	-0.9916	-0.7625	-0.5236
log(odep)	-2.0085	-1.8531	-1.7547	-1.6857	-1.617	-1.5342	-1.4675	-1.2832	-0.6818
$\Delta log(ydep)$	-0.0270	-0.0188	-0.0125	-0.0088	-0.006	-0.0027	‖0.0009	0.0100	0.0340
$\Delta log(odep)$	-0.0020	0.0047	0.0075	0.0101	0.0126	0.0151	0.0173	0.0246	0.0506
money	0.0202	0.04	0.0539	0.0652	0.0778	0.0906	0.1076	0.1549	0.6617
rgdppc	-0.0046	‖0.0072	0.0131	0.0182	0.0229	0.0291	0.0354	0.055	0.2142
ToT	-0.0386	-0.022	-0.0134	-0.0073	-0.0007	‖0.0044	0.0103	0.0365	0.3501
budbal	-0.0168	-0.0102	-0.0065	-0.0035	-0.0006	‖0.0020	0.0049	0.0177	0.1669
pop	0.0007	0.0028	0.0038	0.0049	0.0062	0.0077	0.0093	0.0144	0.2344
LifeExp	-0.2	-0.1	‖0	0.1	0.1	0.2	0.2	0.4	1.4
Mortality	-2	-1	-1	-1	‖0	0	0	0	20

‖ is used to mark where a variable measuring a rate of change becomes positive

Table 16: Table of Variable Values at Various Quantiles

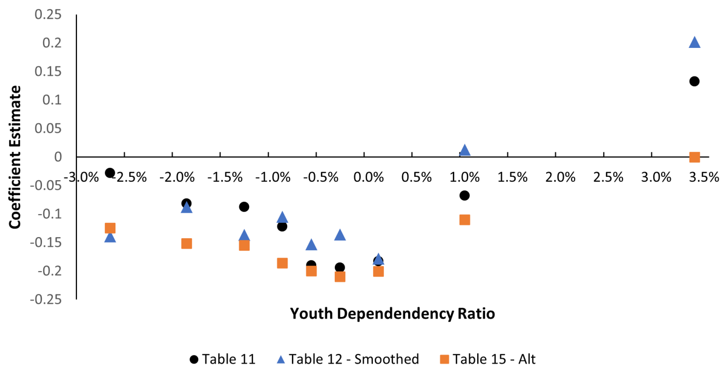


(a) Coefficient estimates of ydep

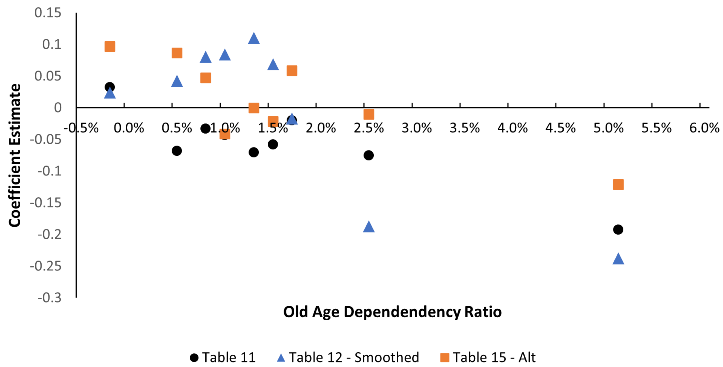


(b) Coefficient estimates of odep

Figure 10: Quantile Regression Coefficient Estimates plotted against a linear distribution of dependant variable values - Levels



(a) Coefficient estimates of Δlog(ydep)



(b) Coefficient estimates of Δlog(odep)

Figure 11: Quantile Regression Coefficient Estimates plotted against a linear distribution of dependant variable values - Rates of Change