Fertility and the Real Exchange Rate

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Comments Welcome!

Abstract

We use a quinquennial data set covering 87 countries between 1975 and 2005 to investigate empirically the relationship between fertility and the real effective exchange rate. Theoretically a country experiencing a decline in its fertility rate can be expected to experience a real depreciation. We test and confirm this hypothesis, controlling for a number of other potential determinants. We find a statistically significant and robust link between fertility and the exchange rate. Our point-estimate is that a decline in the fertility rate of one child per woman is associated with a depreciation of approximately 15% in the real effective exchange rate.

Keywords: empirical, data, cross-country; demographic; effective; multilateral; panel

JEL Classification Numbers: F32, J13

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1. Introduction

Massive demographic changes are in play across the world. UN data show that average world life expectancy at birth rose from 60.2 years in 1975-1980 to 66.0 just twenty-five years later, an increase of 9.6%. Over the same time period, the fraction of the populace aged 65 or more increased from 5.6% to 6.9%. Even more dramatically, the fertility rate (average births per woman) fell from 3.92 to 2.65, a dramatic change of some 48%. These long-run trends are likely to continue; the UN forecasts the global fertility rate in 2050 to be 2.02, when the 65%+ ratio is forecast to be 16.2%. This paper is concerned with the consequences of such demographic issues for international finance. In particular, we focus on the question "What effect does the fertility rate have on the real exchange rate?"

It is not difficult to imagine a theoretical linkage between the fertility rate and the real exchange rate. Suppose the fertility rate declines for some exogenous reason (e.g., an improvement in female education or a decrease in the cost of contraception). Life-Cycle theory argues that child-rearing is associated with increased consumption and thus reduced savings (children tend to consume more than they produce); a drop in fertility can be expected to raise savings. Investment may also drop if there is a decline in the future equilibrium capital stock resulting from a smaller populace. If savings rise and investment falls, the current account improves and a real depreciation of the exchange rate is part of the equilibrium response to an exogenous decline in fertility. Further, the young consume disproportionately high proportions of non-tradeables (as do the old), reinforcing the notion that higher fertility should be associated with real appreciation. This theoretical intuition seems straightforward. However, as with so many theories concerning exchange rates, the real question is whether these theoretical implications are borne out empirically or remain blurred by a myriad of other factors. This paper

is an exploratory data analysis of the linkage between fertility and the exchange rate that is unabashedly empirical in nature.

We gather a broad long panel of data that covers 87 countries between 1975 and 2005, a sample of great demographic change and cross-country heterogeneity. Unlike many theoretical predictions for exchange rates, ours seems borne out by the data. We find a strong link between the real effective exchange rate and the fertility rate. We use fixed-effects panel methods, and account for a number of other reasons why exchange rates adjust, including the Balassa-Samuelson effect, the effects of trade liberalization, government spending, net foreign assets, and so on. Yet we still find that a 1-point decline in the fertility rate is associated with a real effective depreciation of around 15%. This result seems sensible and plausible; it is also robust.

In section 2 we provide a brief survey of the literature; this section can be skipped without loss. We then present a simple theoretical model to frame the problem. Our data set and methodology are presented in section 4, while section 5 contains our key results. Section 6 presents sensitivity analysis, followed by a brief examination of other demographic phenomena. The paper closes with a brief conclusion.

2. Quick Survey of the Literature

Most research that studies the macroeconomic effects of demographic change is concerned with these phenomena at a national level. For instance, there is a lively debate concerning the implications of demographic shifts for stock and bond returns; see, e.g., Poterba (2004). Nevertheless, a strand of the literature has developed recently that is concerned with the implications of demographic changes for the global economy. Two recent references of value

are FRB Kansas City (2004) and Reserve Bank of Australia (2006); see also the survey by Bosworth et al (2004).

Our theoretical analysis below leads to the presumption that an appreciation seems the likely result of increased fertility. This conclusion is disputed. Bryant et al (2004) develop a two-country model which implies that the real exchange rate may be expected to depreciate in the long run following a fertility increase. Cantor and Driskill (2000) show that the sign of the effect depends on whether or not the country is a net debtor; see also the references in Bosworth et al (2004). In this paper, we are not interested in taking any particular theoretical framework too literally. Rather, we add to the debate by using empirical rather than theoretical techniques.

We do this since most of the existing work in this area is theoretical, often using simulation techniques for quantification. For instance, Bryant et al (2004) use simulation methods to study the effects of fertility declines in the international economy, and find that in their model a decline in fertility leads to a real appreciation; see also Bosworth et al (2004), Bryant (2004, 2006), and Higgins and Williamson (1997). Börsch-Supan et al (2002) use simulations to study pension reform and international capital flows that stem from population aging in a multi-country overlapping generations model. Feroli (2003) also uses theory and simulation techniques and finds that demographic differences can explain much of the size and timing of some key current account imbalances; see also Ferrero (2007).

The extant empirical work that estimates the effects of demographic changes tends to be concerned with macroeconomic *quantities* (such as the current account, or savings and investment rates) rather than international *prices*. For instance, Higgins (1998) uses a cross-country panel and finds strong evidence that demographic changes are correlated with current accounts. In particular, his evidence is consistent with standard theory that predicts declines in

savings with the proportions of both the young and the elderly in the population; see also Domeij and Flodén (2006), Helliwell (2004), and Herbertsson and Zoega (1999). Kim and Lee (2007) find that increases in the proportion of dependents in the population lead to decreased savings and deteriorated current accounts using G-7 data and time-series techniques.

The closest antecedents to our paper are by Andersson and Österholm. In their (2005) paper, Andersson and Österholm use Swedish data and time-series techniques and find that using the distribution of the Swedish population across cohorts helps both determine and forecast the real exchange rate. Their analysis includes no real exchange rate determinants other than the age distribution (and two dummy variables). In Andersson and Österholm (2006), they extend the analysis to 25 OECD countries and use a panel of annual data. Again, they find some consistency between life-cycle theory and the effects of the age distribution on the real exchange rate. However, the age distribution does not help in forecasting the exchange rate, and some of their results are sensitive. They consider only one economic control, namely the real interest rate differential, which can be linked theoretically to the change in the real exchange rate. By way of contrast, our approach is medium-run in design, and is more focused on the effects of fertility on the exchange rate level. We cover a broader panel of countries, and allow for a large number of alternative real exchange rate determinants; we also conduct extensive sensitivity analysis.

3. A Simple Model

We motivate our analysis using a simple overlapping generations model that links demographic phenomena to the real exchange rate through two channels. We follow Braude (2000) in assuming a small open economy that faces an exogenous price of tradeables, since this allows us to plausibly take the predictions of the model to the data via a long wide panel of

countries. The young (and old) consume disproportionately high amounts of non-tradeables (education and healthcare respectively). An increase in the fertility rate raises the proportion of the young population and accordingly the demand for non-tradeable goods, resulting in a real appreciation. This effect stems in part from the *composition* of demand for non-tradeable spending that differs systematically by demographic group. A second effect results from the fact that the young (and old) save disproportionately less than the working populace. As the proportion of young (and/or old) in the population rises, savings falls and the demand for both tradeables and non-tradeables rises, again resulting in a real appreciation; the *savings* channel.[1]

More formally, consider economy with three sets of overlapping generations at any point in time t: children (C), workers (W), and retirees (R). Let μ_t denote the number of children, and φ_t the number of retirees. Since the number of workers is normalized to unity, μ_t and φ_t denote the child- and retiree-worker dependency ratios respectively.

A worker earns an after-tax wage of $(w_t-\tau_t)$, which is allocated between his own consumption, his children's consumption, and savings for retirement. Two consumption goods are available; tradeables (C_T) and non-tradeables (C_N). The worker maximizes his utility:

$$U_t = U(C_{NWt}, C_{TWt}) + \beta\mu_t U(C_{NCt}, C_{TCt}) + \rho U(C_{NRt+1}, C_{TRt+1}) \qquad (1)$$

subject to the budget constraint

$$P_{Nt}C_{NWt} + P_{Tt}C_{TWt} + \mu_t(P_{Nt}C_{NCt} + P_{Tt}C_{TCt}) + (1/(1+r^*))(P_{Nt+1}C_{NRt+1} + P_{Tt+1}C_{TRt+1})$$
$$= (w_t-\tau_t) + b/(1+r^*). \qquad (2)$$

The utility function is parameterized as

$$U(C_{Nit}, C_{Tit}) = \alpha_i \log C_{Nit} + (1-\alpha_i)\log C_{Tit}. \qquad i = W, C, R \tag{3}$$

If $\alpha_C, \alpha_R > \alpha_W$ then consumption of children and retirees is biased towards non-tradeables (relative to workers).[2] Workers discount the consumption of their children by a factor β. When the proportion of children in the population (μ) rises, consumption per child falls but the total allocation of consumption to children rises as resources shift away from the consumption and savings of their parents. Future utility during retirement is discounted at rate ρ, while the world interest rate (r^*) is given exogenously to the small open economy.

The retired have two source of income: the interest earnings from savings, and a government transfer payment (b). Denoting the (predetermined) amount of foreign assets that each retiree owns by a_t, the total income of the retirees is $\varphi_t(r^* a_t + b)$.[3] The problem of the old is thus to maximize $[\alpha_R \log C_{NRt} + (1-\alpha_R)\log C_{TRt}]$ subject to this budget constraint.

The government finances the transfer payments (b) via a lump sum tax (τ_t) levied on the current workers. It thus faces a budget constraint of

$$\tau_t = \varphi_t b. \tag{4}$$

The economy produces tradeable and non-tradeables respectively with Cobb-Douglas production functions:

$$Y_{Tt} = L_{Tt}^{\theta T} K_{Tt}^{1-\theta T} \tag{5}$$

$$Y_{Nt} = L_{Nt}^{\theta N} K_{Nt}^{1-\theta N} \qquad (5')$$

where both the total capital stock and its sectoral allocation is given exogenously at time t. The number of workers working in the tradeables (non-tradeables) sector is denoted by L_{Tt} (L_{Nt}). Since there is perfect competition, full employment implies $L_{Tt} + L_{Nt} = 1$.[4]

The price of tradeables is given exogenously to the small open economy. However, the price of non-tradeables (and hence the real exchange rate) is determined domestically by the requirement that the demand for non-tradeables equal their supply. In particular, equilibrium in the non-tradeables market requires:

$$Y_{Nt} = C_{NWt} + \mu_t C_{NCt} + \varphi_t C_{NRt}. \qquad (6)$$

A Change in the Fertility Rate

Solving the model and using the implicit function theorem, it can be determined when the real exchange rate appreciates in response to a change in the child-worker dependency ratio:

$$\partial P_{Nt}/\partial \mu_t > 0 \quad \text{if} \quad [(\alpha_C - \alpha_W) + \alpha_C \rho] > 0 \qquad (7)$$

Workers with more children allocate more of their disposable income to their consumption, at the expense of both their consumption and retirement savings. The shift of expenditure from workers to children raises the demand for non-tradeables if the consumption of children is biased towards these goods (that is, if $\alpha_C > \alpha_W$); the *composition* of spending channel. Reallocation

from savings to consumption also increases the demand for non-tradeables, so long as children consume non-tradeables; the *savings* channel.

A Change in the Retired-Worker Dependency Rate

Similarly, it can be shown when the relative price of non-tradeables rises with the fraction of retirees in the populace:

$$\partial P_{Nt}/\partial \varphi_t > 0 \quad \text{if} \quad a_t(1+r^*)\alpha_R(1 + \beta\mu_t + \rho) + b[(\alpha_R - \alpha_W) + (\alpha_R - \alpha_C) + \alpha_R\rho] > 0 \qquad (8)$$

An increase in the fraction of retirees in the population affects the price level (and hence the real exchange rate) through their two sources of income. The effect through *assets* is in the first term of the right-hand side of (8), while the effect via *transfer payments* is in the second term. The asset effect is always positive; a larger retired population owns more assets and thus spends more. But since the elderly do not work, they raise spending without affecting labor supply. This increases the demand for non-tradeables, and hence their price (in a manner similar to that of the celebrated "transfer effect").[5]

The effect of transfer payments on the real exchange rate drives the second term on the right-hand side of (8). Since transfers are from workers (and thus implicitly the young) to the retired, the effect is similar in interpretation to that of a change in the fertility rate. If the retired spend more heavily on non-tradeables than workers, the real exchange rate will rise with the elderly dependency ratio through both the *composition* and *savings* channels.

While this model is too stylized to be taken directly to the data, it provides a simple analytic framework in which to consider the effects of demographic effects on the real exchange rate. We focus on the comparative static (7), given the remarkable changes in fertility rates experienced during the sample; we also examine (8) briefly. Unfortunately, many such theoretical predictions have worked poorly with exchange rate data in the past, so it is now time to test directly for the effects of demography on real exchange rates.

4. Methodology

We estimate the following equation as our default:

$$\log(reer)_{it} = \beta fert_{it} + \gamma_1 \log(pop)_{it} + \gamma_2 open_{it} + \gamma_3 TL_{it} + \gamma_4 G/Y_{it} + \gamma_5 y/yus_{it} + \Sigma_t \varphi_t + \Sigma_i \theta_i + e_{it} \quad (9)$$

where

- $\log(reer)_{it}$ is the natural logarithm of the average real effective CPI exchange rate for country i over quinquennial time period t (taken from IFS),
- fert is the fertility rate measured in children per woman (UN),
- pop is the population (PWT)
- open is the ratio of exports plus imports to GDP (PWT),
- TL is a measure of trade liberalization (Wacziarg-Welch),
- G/Y is the government share of GDP (PWT),
- y/yus is the ratio of current per capita GDP relative to the United States (PWT),
- $\{\gamma\}$ is a set of nuisance coefficients,

- $\{\varphi\}$ is a set of time-specific effects,
- $\{\theta\}$ is a set of country-specific effects, and
- e is a well-behaved disturbance term.

The coefficient of interest to us is β, the effect of fertility on the log real effective exchange rate. We focus on the fertility effect initially, since it has experienced great change during the sample; later on, we extend our analysis to examine other demographic effects. We estimate this reduced-form equation with least squares (with robust standard errors), including comprehensive sets of both time- and country-specific fixed effects.[6] Thus, ours is a "within" estimator that accounts for time-invariant national phenomena (e.g., political institutions or geographic features). We are also allowing for phenomena that are common to a period of time (e.g., oil prices or global business cycles) when we estimate our key coefficient. Thus β can be interpreted as the exchange rate effect on a country when its fertility rate falls, holding the global fertility rate constant.[7]

Our default equation includes the usual suspects for medium- and long-run real exchange rate determination. We include five controls above and beyond fertility (and fixed effects): 1) the ratio of national to American real GDP per capita (measured in international $); 2) the ratio of GDP spent directly by the government; 3) a binary measure of trade liberalization; 4) openness (trade as a proportion of GDP); and 5) the log of the country's population. The motivations for these controls are straightforward (we provide the intuition briefly below), all five of these variables are potentially relevant controls, and each has been suggested in the literature as being of possible import. Still, there is little evidence that any of these variables

play a consistently strong role in real exchange rate determination in practice, simply because real exchange rates are notoriously difficult to model empirically (Rogoff, 1996).

Real GDP per capita (measured as a ratio to its American analogue) is included as a proxy for the celebrated "Balassa-Samuelson" effect. This states that rich countries should have higher price levels than those of poor countries, because of relatively higher productivity in the tradable goods sector (so γ_5 should be positive) . Non-traded goods tend to be services which cannot take advantage of technological superiority to the same extent as tradeables (think of haircuts). Thus if tradeable productivity rises in a small country facing fixed prices of tradeables, wages grow, and the relative price of non-tradables must rise.[8] Rogoff (1996) presents this reasoning in greater detail and links the real exchange rate empirically to our proxy (the ratio of foreign to American real per capital GDP). More generally, the Balassa-Samuelson effect links economic development to real exchange rate appreciation. While this effect has been much investigated, Froot and Rogoff (1995, p1648) state "… the empirical evidence in favor of a "Balassa-Samuelson" effect is weaker than commonly believed …"[9]

The fraction of output spent by the government positively affects the real exchange rate if governments tend to demand disproportionately non-traded goods, as noted by Froot and Rogoff (1995). This ratio affects the relative demand for non-tradeables (where the Balassa-Samuelson effect is on the supply side), and has been used repeatedly in the empirical literature; see e.g., De Gregorio, Giovannini and Wolf (1994) Chinn and Johnston (1996).

There is a general theoretical presumption in the literature that trade liberalization should lead to a depreciation of the real exchange rate. The intuition is that liberalization is associated with a relative increase in the demand for imports, so that a real depreciation is necessary to maintain internal and external balance; Li (2003), and Edwards and Ostry (1990). This is closely

linked to the issue of openness, which can be either natural (because, e.g., of a country's size or geography), or artificial (induced by liberal trade policy or history). As a country becomes more open, the prices of its tradeable goods tend to fall, lowering the equilibrium real exchange rate; also see Hau (2002).

Finally, we include the log of a country's population just to see if size matters. Smaller countries may find it easier to pursue mercantilist exchange rate policy, so that one might expect population to have a positive effect on the real exchange rate.

We are interested in exploring the sensitivity of our key findings extensively. Accordingly, we also estimate three variants of our default model. The first two models each add a pair of potentially relevant variables, while the third removes a pair of controls from the default model.

Our first model variant adds a different pair of controls to the default model: a) the ratio of net foreign assets to GDP emphasized by Cantor and Driskill (2000) and Lane and Milesi-Ferretti (2006), and b) the current account imbalance, again measured as a percentage of GDP. Net foreign assets is a variable of considerable appeal, since net debtors need in principle to have depreciated exchange rates to generate the trade surpluses required to service debt payments and maintain net foreign asset sustainability. While these variables are of interest, their inclusion reduces the sample size considerably.[10]

Our second variant adds to the default model: a) the growth rate of per capita real GDP; and b) the deviation from absolute purchasing power parity (PPP). The first variable is added in case the *level* of real GDP per capita (relative to the United States) is a poor proxy for the Balassa-Samuelson effect. Since faster growing countries should experience appreciation over the long run for this reason, the coefficient should be positive. The second is added in case real

exchange rates move strongly towards absolute PPP, a much-disputed hypothesis; Taylor and Taylor (2004) provide a recent survey (see also Rogoff, 1996). We measure both growth rates and the PPP deviation using data from the Penn World Table 6.2.[11]

Our third model variant drops both government consumption and the ratio of domestic to American income. We choose to drop these variables simply because their coefficients are typically insignificantly different from zero at conventional confidence levels in our default model.

The Data Set

Almost all of our series are drawn from standard data sets; a data appendix describes the variables in more detail and provides their sources. The two biggest constraints we face are: a) the limited amount of comprehensive data on demographic phenomena, and its overlap with b) the real effective exchange rate.

The Population Division of the United Nations provides series for a large number of countries on life expectancy and the fertility rate. The changes in fertility rates during our sample period are dramatic. For instance, the Spanish fertility rate fell from 2.6 (children per woman) in 1975-1980 to only 1.3 in 2000-2005, while China's fertility fell from 3.3 to 1.7 during the same period of time. Fertility rates are also uneven; during the 2000-2005 period, both the Russian and Japanese fertility rates were 1.3, while that of Pakistan was 4.3 and the Nigerian fertility rate was 5.9. The series are provided at five-year intervals and are averaged over quinquennial periods (so that they span e.g., July 1975 through June 1980). The series begin in 1950 and are forecast through 2050.

Figure 1 contains quinquennial box and whiskers plots for the fertility rate data we use. The box covers the range of data between the 25th and 75th percentiles; the median is marked inside the box with a bar (it is slightly lower than the global average); the whiskers extend out to the rest of the distribution.[12] Two distinct features of the data are apparent. First, fertility rates are trending lower over time. Second, there is enormous cross-country variation in fertility. Our methodology takes both phenomena into account.

The International Monetary Fund provides data on the real effective exchange rate (REER) for over ninety countries through its *International Financial Statistics* database, beginning in 1975. While six different variants are available, we rely on the only one available for a large number of observations; it is based on relative CPIs (IFS mnemonic "rec").[13] This variable is set such that 2000=100 for all countries; higher values represent more real appreciation. The series have been checked and corrected for errors.

Real exchange rate series are available from 1975 through 2005 for 91 countries; however the UN does not provide demographic data for four of these (Antigua & Barbuda, Dominica, Grenada, and St. Kitts & Nevis). Accordingly, our sample consists of six quinquennial observations for 87 countries between 1975 and 2005 for a maximum of 522 observations (though some are missing).[14] This is a span of data that would be considered appropriate for medium- or perhaps long-run analysis in international finance. However it is approximately the length of a single generation, and thus can not reasonably capture long-run or steady state equilibrium for demographic phenomena (such as those examined by Bryant, 2004, 2006). This is especially true since our data come from a period of time commonly considered to be part of a demographic transition towards lower fertility rates. During this sample, 76 of the

87 countries experienced declines in fertility. Most of these falls were large; 55 were declines of at least 25%. No country experienced a large increase in fertility.

The countries with both demographic and REER observations are tabulated in Appendix Table A1. The top-left graph in Figure 2 contains a scatter of the REER plotted against the fertility rate; immediately to the right is the analogue in natural logarithms. The wide dispersion of the observations masks the positive unconditional correlation between the real exchange and fertility rates. Accordingly, we scatter the log of the real exchange rate against the level of fertility (the log-level specification that we use in much of our empirical work) in the lower-right of the figure, but only after trimming the 5% outliers from both tails of both variables.

We use conventional sources for our other series. The Penn World Table 6.2 provides series on: population, openness, the ratio of government spending to output, the ratio of national to American real GDP per capita, growth, and absolute bilateral PPP-deviations. The binary measure of trade liberalization is provided by Wacziarg and Welch (2003); Lane and Milesi-Ferretti (2006) provide net foreign assets. Further details are provided in a data appendix, as are descriptive statistics.

5. The Baseline

Our benchmark results are presented at the left-hand side of Table 1. Three of the control variables are statistically significant. Larger economies have more depreciated real exchange rates, while more open and liberal economies tend to have more appreciated currencies. Neither government spending (relative to GDP) nor real income per capita (relative to the United States) exert statistically significant effects on real exchange rates. The equation does not explain much

of the variation in the (log-) real effective exchange rate. The within-country R^2 is a moderately respectable .47, but the between-countries and overall R^2 statistics are less than.01.

The most important result is tabulated in the top row, which presents β, the effect of the fertility rate on the (log-) REER, *ceteris paribus*. Consistent with theory, it is positive; decreases of fertility from say 3 to 2 children per woman leads to a real depreciation of 15%.[15] This is of plausible economic size, being neither trivial nor incredibly large. It is statistically significant, with a robust t-ratio of 2.6 which is different from zero at the .01 confidence level.

The columns immediately to the right provide three variants on the default specification. The first variants add a pair of controls each (discussed above), while the third variant removes the two statistically insignificant controls from the default model. None of these modifications affects the point estimate or statistical significance of the fertility effect much; the same is true when all the controls are dropped and the fertility effect is estimated in a bivariate model (though still with time- and country-specific fixed effects). In all cases, the effect of fertility on the real exchange rate is close to .15, and both economically and statistically significant.

6. Sensitivity Analysis

Table 2 contains the results of a number of robustness checks intend to check whether estimates of β are sensitive to our exact econometric methodology. We perturb the model in nineteen ways, and present estimates for the fertility rate coefficient in both the default model of Table 1 as well as the three variants (nuisance coefficients are not reported to conserve space). Readers in a hurry can skip this section; our key finding is robust.[16]

We begin by adding other variables that are potential determinants of the real exchange rate. While the nominal exchange rate regime is often linked to the *volatility* of the *nominal*

exchange rate in the short run, there is little evidence that it is tied to the *level* of the nominal exchange rate over the medium run, let along the medium-run level of the *real* exchange rate. Nevertheless, we have added a dummy variable representing the prevalence of *de facto* fixed exchange rate regimes (we use the measure of Reinhart and Rogoff, 2004). Next, we add a standard measure of political institutions, the measure of constraints on the executive drawn from the Polity 2 data set. We then added a measure of the terms of trade.[17] However, none of these additions much affects either the size or significance of our key coefficient.

Our next set of checks uses different models of the country-specific effect. In turn, we: a) simply *drop* the country-specific fixed effects; b) substitute country-specific *linear time trends* in place of country-specific *intercepts*; and c) replace fixed with *random* effects. However, the effect of fertility on the real exchange rate remains positive and statistically significant throughout these checks.

We have also changed the estimation strategy in a number of ways. First, we try weighting by both log-population and log-GDP. Weighted least squares however delivers much the same results as OLS. We have also added a lag of the dependent variable and re-estimated our equation with the Arellano-Bond procedure.[18] None of these checks alter our key finding much, though the first variant of our model no longer has a statistically significant fertility coefficient when a lagged dependent variable is included.

A more serious issue is that of measurement error. While we think that the fertility rate is plausibly exogenous with respect to the real exchange rate, the fertility rate is neither perfectly (or even comparably) measured, nor perfectly matched to the youth-worker dependency ratio of the theoretical section above. For both reasons, we estimate our equation with instrumental variables for fertility, taking advantage of the fact that fertility has been closely linked in the

demographic literature with female education. For measures of the latter, we take advantage of the updated Barro-Lee data set, which provides series on education at 5-year intervals from 1960. [19] We use three instrumental variables for the fertility rate: 1) the percentage of 15+ females without schooling; 2) the percentage of 15+ females who attained secondary school; and 3) the average years of school for 15+ females. Our IV results for our model and its three variants are all statistically significant; they are not only positive but even larger than our OLS estimates.[20]

Our default equation models the natural logarithm of the exchange rate as a function of the level of the fertility rate. We have checked this semi-log model against a log-log alternative, and find that they all result in economically and statistically significant positive coefficients.[21] We also checked whether the exact data frequency is critical by moving from quinquennial to decadal averages. Again, we find essentially similar results.

Finally we have cut the sample up in a number of different ways. First, we dropped all observations with residuals that lay at least two standard deviations from zero. This has little effect; our results are not being driven by outliers. To check the sensitivity of the results over time we dropped the first third of the observations. This perturbation reduces the precision of our estimates considerably, but the fertility effect remains positive (though it is of more marginal statistical significance). We then used the World Bank's Country Classifications to group our countries by region, allowing us to drop developing countries from: a) Latin America and the Caribbean; and b) Sub-Saharan Africa. We separately also drop all high-income countries. However, none of these checks shake our confidence in the basic result. The effect of the fertility rate on the log of the real effective exchange rate is always estimated to be positive, with a semi-elasticity of around 15. Almost all the estimates of β reported in Table 2 are precisely estimated and significantly different from zero; it is never significantly negative.

Non-Linearities in the Relationship

We can see little evidence in the data of any particular non-linear relationship between the real exchange rate and fertility. The lower-left graph of figure 2 is a scatter-plot of the log real effective exchange rate against the fertility rate, after each variable has had the effects of all the other controls removed.[22] There are few indications of any economically sensible relationship more complicated than that of linearity, and indeed simple checks for asymmetric effects of fertility increases/decreases deliver nothing. Nevertheless, in Figure 3 we plot the fitted values of a non-parametric relationship between the (log of the real effective) exchange and fertility rates, once all other effects have been purged through linear regressions.[23] Most of the fitted values fit inside the +/- 2 standard error confidence interval around the linear relationship, which is also provided. We conclude that there is little evidence of any important non-linearity in the relationship between fertility and the real exchange rate.

7. Dependency Ratios and Other Demographic Measures

While the primary focus of this paper is on the relationship between fertility and the real exchange rate, we now examine four other demographic measures.

The theoretical model which we use as a framework focuses attention not on the fertility rate, but rather on the size of the young relative to the working population; the youth-worker dependency ratio. The same model also allows us to draw out implications for the elderly-worker dependency ratio. While we do not wish to take the model too literally, it is certainly feasible to examine the effects of both these ratios on the real exchange rate. We do this by replacing the fertility ratio in equation (9) successively with the youth- and elderly-worker

dependency ratios. We use the same UN data set which contains the fertility rate, and define youth as being people under the age of 20, while the elderly are defined as those over the age of 64.

The results shown at the bottom of Table 2 show that increases in the ratio of either the young (below 20) or elderly (above 65) to workers (aged 20-64) are also associated with real appreciations. This is true for the default model and all three variants thereof. However, while all these findings are consistent with theory, none are statistically significantly different from the hypothesis of no effect at all. This is disappointing but perhaps unsurprising, given that dramatic changes in the dependency ratios have yet to emerge in the actual data, at least by comparison with the large changes in fertility ratios. In Table A3, we show descriptive statistics for the residuals of the fertility rate and both dependency ratios, after the effects of the other control variables (and time- and country-specific fixed effects) have been taken out through least squares regressions. The fertility rate shows considerably more variation, which may account for the poor precision of the coefficients for the dependency ratios.

As discussed in the theoretical section above, one reason why the real exchange rate might appreciate with increased fertility is that savings might reasonably be expected to fall; investment rates may also rise. It is thus appropriate to ask if there is any evidence that either savings or investment actually respond to fertility rate changes in this way. We provide a tidbit of information in Table 3. From the Penn World Table, we gather information on the proportion of output spent on investment, as well as the analogue for national savings (defined as national income minus both private consumption and government spending). We do not develop models for either the savings or investment rates, and simply regress them separately on fixed time- and country-specific fixed effects, as well as the fertility rate. That is, we include no conditioning

variables at all. Since we take no account of the source or nature of historical and anticipated shocks, these should be viewed as indicative findings at most. Still, the coefficients are consistent with the basic life-cycle framework; fertility rate increases are associated with a fall in savings and an increase in the investment rate. These results are consistent with Herbertsson and Zoega (1999), Kim and Lee (2007), and most of the literature (discussed in Section 2 above). Curiously, when we use the World Bank's measure of the current account (derived from balance of payments data) the results are weaker.[24]

Almost all the results of this section are consistent with our fertility finding, and collectively they add somewhat to our level of confidence. However, the results for demographic variables other than the fertility rate are sometimes statistically weak and we do not wish to overstate their strength. This remains an area for future research.

8. Conclusion

This is a straightforward paper, by design. It does not attempt to make any serious contribution in terms of theory, methodology, or data. Any interest in this paper lies in its estimates.

Real exchange rates are difficult to model empirically; while theories abound, there is only weak empirical evidence supporting quite plausible theories like purchasing power parity and the Balassa-Samuelson effect. In this paper, we provide some rare good news for researchers in the area. In particular, we find that a country experiencing a decline in its fertility rate experiences a real depreciation, holding other things constant. This effect seems plausible and robust. We think of this a good place to pass the torch to others.

Table 1: Benchmark Results

	Default	Variant 1	Variant 2	Variant 3	Bivariate
Fertility Rate	.15**	.17*	.14**	.15**	.19**
	(.06)	(.08)	(.04)	(.06)	(.03)
Log(population)	-.74**	-.49*	-.18	-.71**	
	(.22)	(.23)	(.21)	(.21)	
Openness	.0021**	.0013*	.0015**	.0023**	
%GDP	(.0005)	(.0005)	(.0005)	(.0004)	
Trade Liberalization	.11*	.11	.17**	.10	
Measure	(.05)	(.06)	(.04)	(.05)	
Government Spending	-.002	.006	.002		
% GDP	(.004)	(.005)	(.004)		
Real Income p/c as	.002	.002	-.001		
% US Income p/c	(.002)	(.002)	(.002)		
Net Foreign Assets		.006*			
% GDP		(.005)			
Current Account		-.005			
%GDP		(.003)			
Growth real GDP			-.01		
per capita			(.01)		
PPP-deviation			.009**		
			(.002)		
Observations	336	282	332	336	420
Within R^2	.47	.43	.68	.46	.35

OLS coefficients; those significantly different from zero at 5% (1%) marked by one (two) asterisk(s).
Robust standard errors in parentheses.
Regressand is natural logarithm of real effective exchange rate based on CPI.
Fixed period and country effects included but not reported.
Quinquennial (five-year averages) for 87 countries, spanning 1975 through 2004.

Table 2: Sensitivity Analysis

	Default	Variant 1	Variant 2	Variant 3
Add RR *de facto* exchange rate peg dummy	.22** (.07)	.20* (.10)	.20** (.05)	.22** (.06)
Add Executive Constraints	.20** (.07)	.21** (.08)	.12** (.04)	.20** (.06)
Add Terms of Trade	.14** (.05)	.15* (.07)	.14** (.03)	.14** (.05)
Without country-specific fixed effects	.06** (.01)	.10** (.02)	.04** (.01)	.05** (.01)
Country-specific linear trends (not intercepts)	.19** (.04)	.22** (.04)	.15** (.04)	.16** (.02)
Country-Specific Random (not fixed) effects	.10** (.02)	.13** (.03)	.09** (.02)	.08** (.02)
Weighted by log population	.16** (.06)	.18** (.09)	.15** (.04)	.16** (.06)
Weighted by log GDP	.16** (.06)	.17* (.08)	.15** (.04)	.16** (.06)
Add lagged dependent variable	.18** (.05)	.05 (.05)	.09* (.04)	.19** (.05)
Instrumental Variables	.29** (.09)	.19* (.08)	.26** (.07)	.25** (.09)
Log (not level) of fertility	.39** (.16)	.37 (.22)	.36** (.11)	.40** (.16)
Decadal data	.12* (.05)	.07 (.06)	.08** (.03)	.12** (.05)
Without $>\|2\sigma\|$ outliers	.08** (.02)	.11** (.03)	.13** (.02)	.08** (.02)
Drop 1975-1985	.23* (.10)	.24 (.14)	.10 (.06)	.23* (.10)
Drop Latin America, Caribbean	.15** (.06)	.17* (.09)	.15** (.04)	.15** (.06)
Drop Sub-Saharan Africa	.22** (.05)	.20** (.08)	.18** (.04)	.22** (.05)
Drop high income countries	.17* (.08)	.23 (.12)	.17** (.05)	.15* (.08)
Youth (<20)-Worker Dependency ratio (not fertility rate)	.09 (.21)	.05 (.20)	.25 (.19)	.09 (.21)
Old (>64) -Worker Dependency ratio (not fertility rate)	1.02 (.81)	.88 (.83)	.88 (.50)	.93 (.79)

Coefficient of fertility rate (except for bottom two rows); robust standard errors in parentheses (IV standard errors are conventional). Coefficients significantly different from zero at 5% (1%) marked by one (two) asterisk(s).
Regressand is natural logarithm of real effective exchange rate based on CPI.
OLS estimation, except where noted. Regressors included in default specification but not recorded are: 1) log population; 2) openness (% GDP); 3) Wacziarg-Welch measure of trade liberalization ; 4) government spending (% GDP); 5) real income per capita as % of US income per capita; 6) time effects; 7) country-specific fixed effects.
Variant 1 adds: 1) net foreign assets (% GDP); and 2) current account (% GDP). Variant 2 adds: 1) PPP-deviation; and 2) growth in real GDP per capita. Variant 3 removes: 1) government spending (% GDP); and 2) real income per capita as % of US income per capita.
Instrumental Variables estimation; IVs taken from Barro-Lee: 1) percentage of 15+ females without schooling; 2) percentage of 15+ females attained secondary school; and 3) average years of school for 15+ females.
Quinquennial (five-year averages) for 87 countries, spanning 1975 through 2004 (1999 for IV estimation).

Table 3: Bivariate Effect of Fertility on Savings, Investment, and the Current Account

Regressand	Fertility Effect	Observations
Savings Rate, % GDP (PWT)	-1.67* (.75)	452
Investment Rate, % GDP (PWT)	2.41** (.43)	452
Current Account, % GDP (WDI)	-.21 (.67)	393

Coefficient of fertility rate; standard errors in parentheses. Coefficients significantly different from zero at 5% (1%) marked by one (two) asterisk(s).
Regressand is rate based on CPI.
OLS estimation. Time and country-specific fixed effects included but not recorded.
Quinquennial (five-year averages) for 87 countries, spanning 1975 through 2004.

Figure 1: Box and Whisker Plots of the Global Fertility Distribution

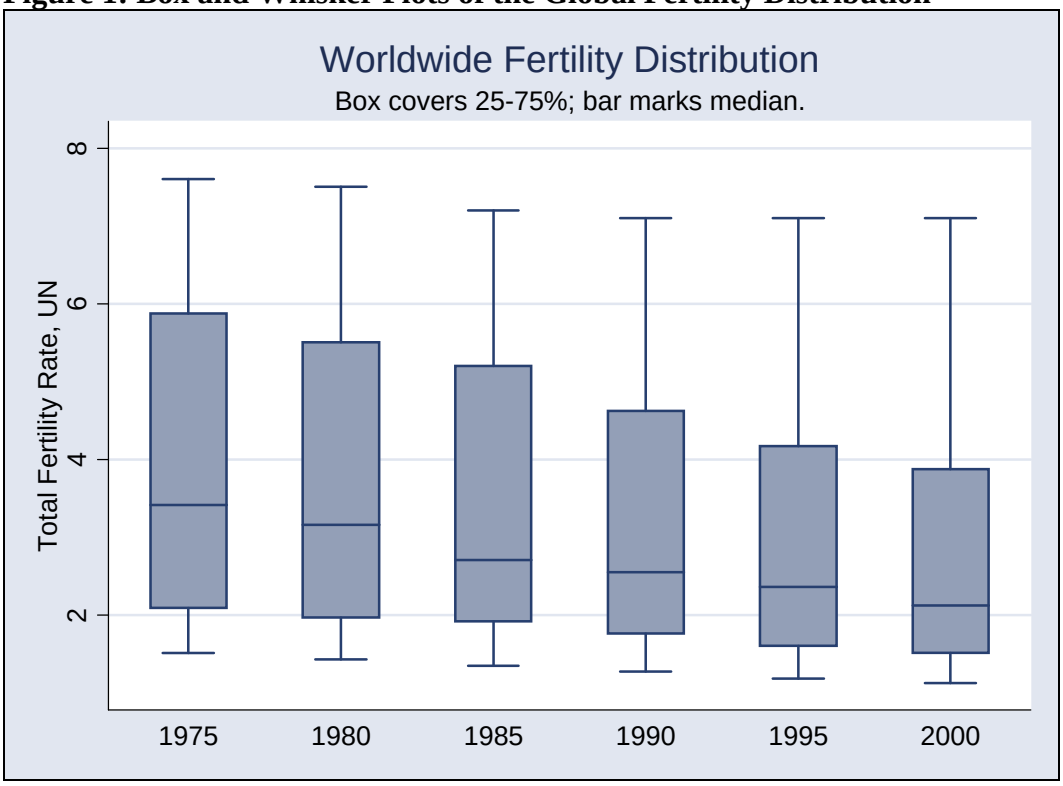


Figure 2: Bivariate Scatterplots of Key Variables

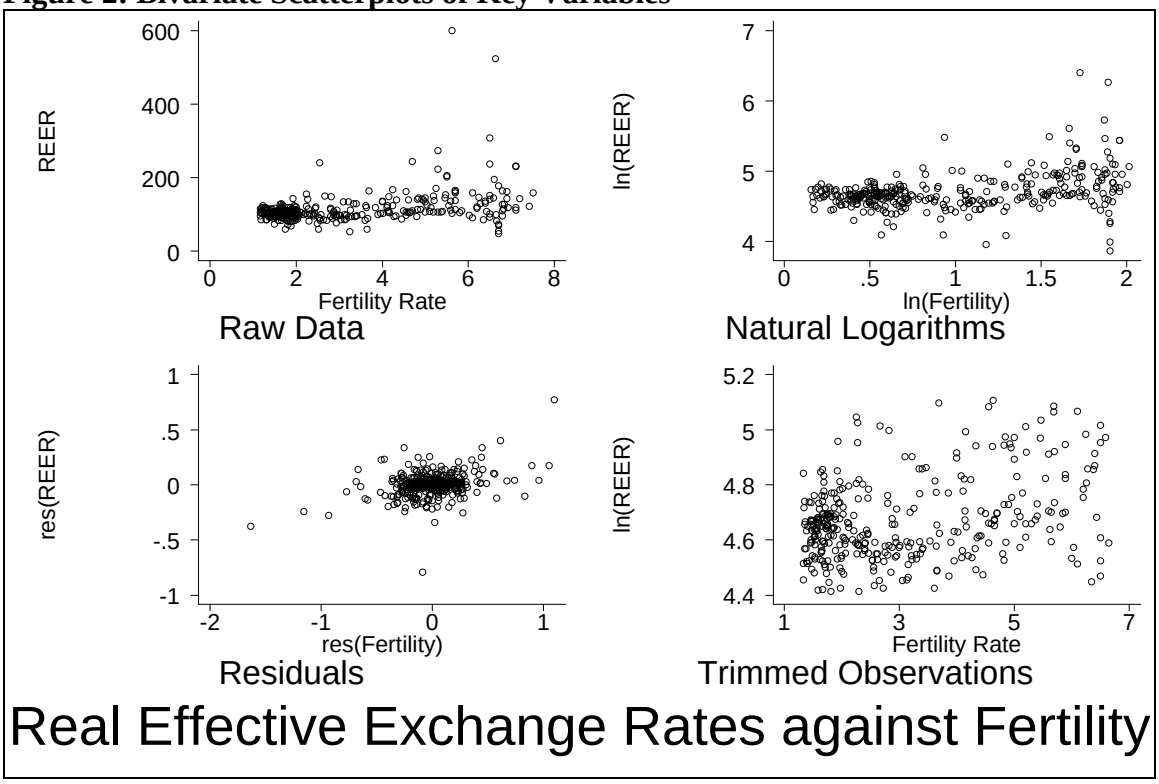
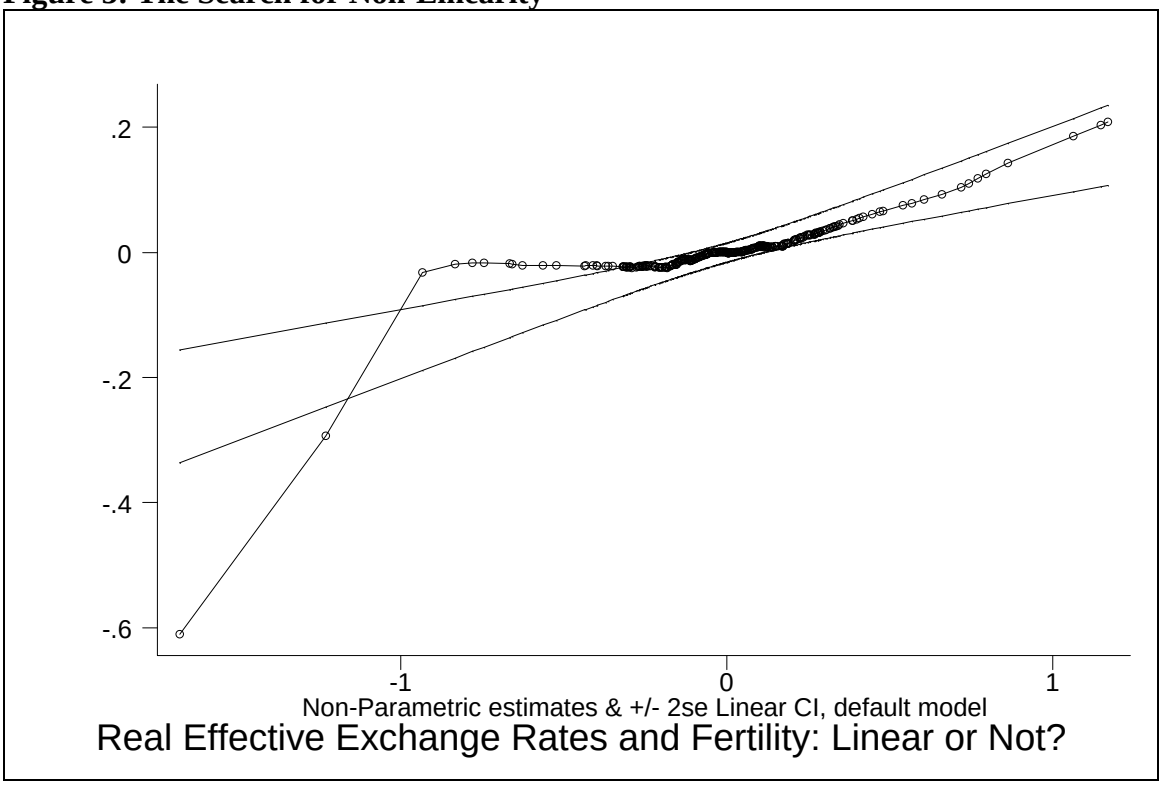


Figure 3: The Search for Non-Linearity



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Appendix Table A1: Country List

Algeria	Armenia	Australia
Austria	Bahamas	Bahrain
Belgium	Belize	Bolivia
Bulgaria	Burundi	Cameroon
Canada	Central African Rep.	Chile
China	Colombia	Congo/Zaire
Costa Rica	Croatia	Cyprus
Czech Republic	Côte d'Ivoire	Denmark
Dominican Republic	Ecuador	Equatorial Guinea
Fiji	Finland	France
Gabon	Gambia	Germany
Ghana	Greece	Guyana
Hungary	Iceland	Iran
Ireland	Israel	Italy
Japan	Lesotho	Luxembourg
Macedonia, FYR	Malawi	Malaysia
Malta	Moldova	Morocco
Netherlands	Netherlands Antilles	New Zealand
Nicaragua	Nigeria	Norway
Pakistan	Papua New Guinea	Paraguay
Philippines	Poland	Portugal
Romania	Russia	Samoa
Saudi Arabia	Sierra Leone	Singapore
Slovak Republic	Solomon Islands	South Africa
Spain	St. Lucia	St. Vincent & Grenadines
Sweden	Switzerland	Togo
Trinidad and Tobago	Tunisia	Uganda
Ukraine	United Kingdom	United States
Uruguay	Venezuela	Zambia

Appendix Table A2: Descriptive Statistics

	Obs.	Mean	Std. Dev.	Min	Max
Log(Real Effective Exchange Rate)	443	4.69	.27	3.9	6.4
Fertility Rate	522	3.36	1.86	1.1	7.6
Log(population)	546	8.55	2.06	3.7	14.1
Openness, %GDP	472	80.24	53.93	8.9	406.7
Trade Liberalization Measure	462	.59	.48	0	1
Government Spending, %GDP	472	22.76	10.74	4.6	67.9
Real Income p/c, % US Income	472	38.35	30.19	1.1	137.9
Growth real GDP per capita	462	1.67	3.68	-10.4	48.2
PPP-deviation	472	66.59	34.31	15.3	195.2
Net Foreign Assets, %GDP	387	-35.67	76.21	-980.	184.
Current Account, %GDP	409	-3.08	6.8	-30.4	21.4

Appendix Table A3: Descriptive Statistics for Orthogonalized Variables

	Mean	Standard Deviation	Maximum	Minimum
Fertility rate, Default Model	0	.31	-1.78	1.16
Fertility rate, Variant 1	0	.27	-1.75	1.10
Fertility rate, Variant 2	0	.31	-1.85	1.12
Fertility rate, Variant 3	0	.31	-1.84	1.15
Youth (<20)-Worker Dependency ratio, Default Model	0	.06	-.23	.18
Youth (<20)-Worker Dependency ratio, Variant 1	0	.05	-.18	.16
Youth (<20)-Worker Dependency ratio, Variant 2	0	.05	-.22	.17
Youth (<20)-Worker Dependency ratio, Variant 3	0	.06	-.23	.18
Old (>64) -Worker Dependency ratio, Default Model	0	.01	-.03	.06
Old (>64) -Worker Dependency ratio, Variant 1	0	.01	-.04	.05
Old (>64) -Worker Dependency ratio, Variant 2	0	.01	-.03	.06
Old (>64) -Worker Dependency ratio, Variant 3	0	.01	-.03	.06

Descriptive statistics for residuals from OLS regressions. Regressors included in default specification are: 1) log population; 2) openness (% GDP); 3) Wacziarg-Welch measure of trade liberalization ; 4) government spending (% GDP); 5) real income per capita as % of US income per capita; 6) time effects; 7) country-specific fixed effects. Variant 1 adds: 1) net foreign assets (% GDP); and 2) current account (% GDP). Variant 2 adds: 1) PPP-deviation; and 2) growth in real GDP per capita. Variant 3 removes: 1) government spending (% GDP); and 2) real income per capita as % of US income per capita.
Quinquennial (five-year averages) for 87 countries, spanning 1975 through 2004.

Appendix Table A4: Data Appendix
The main elements of the data set were gathered in March 2007.

International Financial Statistics (March 2007) from International Monetary Fund (http://ifs.apdi.net)

- CPI-based real effective exchange rate, an index number where an increase represents appreciation, set to 100 for all countries for the year 2000 (mnemonic "xxx..RECXF…" where xxx is the country's 3-digit IFS country code).

World Population Prospects (2004 Revision) from Population Division, Department of Economic and Social Affairs, United Nations Secretariat (http://esa.un.org/unpp)

- Total fertility rate, number of children per woman. Based on national sources (further details available at http://esa.un.org/wpp/sources/country.aspx).

Penn World Table (Mark 6.2) from Center for International Comparisons, University of Pennsylvania (http://pwt.econ.upenn.edu/)

- Population, in thousands (mnemonic "pop").
- Openness; Exports plus Imports as percentage of GDP, in constant prices (mnemonic "openk").
- Government Spending, as share of Real GDP in constant prices (mnemonic "kg").
- Real Income per capita as percentage of American Income per capita (mnemonic "y").
- Real GDP per capita, in constant prices, Laspeyres index with 1996 reference year (mnemonic "rgdpl").
- Price Level of GDP is purchasing power over GDP divided by the exchange rate, both expressed as national current units per US$, in percentage terms. An index number; US=100 in current prices (mnemonic "p").
- National Savings, as share of Real GDP in constant prices (constructed as 100-kc-kg where "kc" is mnemonic for Consumption Spending as share of Real GDP).
- Investment, as share of Real GDP in constant prices (mnemonic "ki").

Wacziarg-Welch Measure of Trade Liberalization from Romain Wacziarg (http://www.stanford.edu/~wacziarg/downloads/liberalization.xls)

- An updated version of the Sachs-Warner dummy measure of openness, relying on tariff and non-tariff barriers, black market premia, marketing boards, and so forth. 1 represents an open/liberalized country, 0 closed.

The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970-2004 from Philip Lane and Gian-Maria Miles-Ferretti (http://www.imf.org/external/pubs/ft/wp/2006/data/wp0669.zip)

- Net Foreign Assets, as percentage of GDP, all measured in dollars.

World Development Indicators (March 2007) from World Bank (http://publications.worldbank.org/WDI/)

- Current Account imbalance, as percentage of GDP (mnemonic "BN.CAB.XOKA.GD.ZS")

World Bank Country Classifications (March 2007) from World Bank (http://siteresources.worldbank.org/DATASTATISTICS/Resources/CLASS.XLS)

- Dummy variable country groupings for: a) developing countries in Latin America and Caribbean; b) developing countries in Sub-Saharan Africa; and c) high income countries.

Reinhart-Rogoff Exchange Rate Regime Classifications from Carmen Reinhart (http://www.publicpolicy.umd.edu/faculty/reinhart/annual1.dta),

- Dummy variable for fixed exchange rate regime (mnemonic "gcode" <3). Unity where the most common regime during the year is any of: a) no separate legal tender; b) pre-announced peg or currency board arrangement; c) pre-announced horizontal band that is narrower than or equal to +/-2%; d) *de facto* peg; e) pre-announced crawling peg; f) pre-announced crawling band that is narrower than or equal to +/-2%; g) *de facto* crawling peg; and h) *de facto* crawling band that is narrower than or equal to +/-2%.

Polity IV Project from CIDCM, University of Maryland (http://www.cidcm.umd.edu/polity/)

- Executive Constraints (mnemonic "xconst"). An index ranging from 1 to 7, where 7 represents executive parity or subordination, and 1 represents unlimited authority.

World Economic Outlook from IMF (I thank Gian-Maria Milesi-Ferretti for assistance)

- Terms of Trade for Goods and Services (mnemonic "WxxxTT" where xxx is the country's 3-digit IFS country code). An annual index number set to 100 for all countries for the year 2000.

International Data on Educational Attainment (Updated 'Barro-Lee' Data Set) from CID Harvard University (http://www.cid.harvard.edu/ciddata/ciddata.html)

- Percentage of 15+ females without schooling (mnemonic "luf").
- Percentage of 15+ females who attained secondary school (mnemonic "lsf").
- Average years of school for 15+ females (mnemonic "tyrf").

Endnotes

[1] Braude (2000) notes the existence of a third channel for the elderly, similar to the transfer problem.
[2] The young consume disproportionately high amounts of (non-tradeable) education, while the old consume relatively high amounts of (non-tradeable) health care, so this presumption seems reasonable. Still, this issue is ultimately empirical, since workers may consume disproportionately high amounts of (non-tradeable) housing.
[3] Braude (2000) shows that the assumption that the retired only hold foreign assets is an inessential simplification.
[4] One could generalize the model to handle endogenously determined labor supply and/or taxes.
[5] In the absence of perfect capital mobility, there may also be supply effects as the assets owned by retirees rise; Braude (2000).
[6] We do not see strong evidence of non-stationarity empirically, and the residuals from (9) seem to have little auto-correlation.
[7] Bryant (2004) refers to this as an "asymmetric" effect. Note that if all national fertility rates fall by the same amount this effect would be picked up by the time effect and no exchange rate movement would be predicted.
[8] It would be interesting to include a measure of relative productivity in tradeable and non-tradable sectors, but estimating such productivity ratios for this panel of data is beyond the scope of the paper.
[9] Real GDP per capita may also be included as a proxy for non-homothetic preferences, since the demand for services may rise with income; Chinn (1997).
[10] The current account may also be endogenous.
[11] Prices are expressed relative to those of the United States (the latter's price level is equal to 100), so this is a *bilateral* measure of PPP. We use it with our *multilateral* exchange rate index since a) the US is always one of the richest countries in the sample, and b) we include period-specific fixed effects to take account of common shocks, such as general fluctuations in the value of the American dollar. Since lower values represent a lower cost of living (compared to the US), its coefficient might be expected to be positive.
[12] There are no outliers in the sense of observations that lie more than 150% away from the edges of the interquartile range.
[13] The CPI-based multilateral real exchange rate is available for more than four times as many observations as its closest competitor (which is based on relative normalized unit labor costs).
[14] Other authors have also used five-year averages to smooth out short-run influences and reduce the autoregressive nature of the data; see e.g., Higgins (1996). We create our quinquennial observations by weighting annual data appropriately, wherever possible. For instance, in constructing the 1975-1980 observation, we put weights of .5 on both 1975 and 1980 observations and unity on those for the intervening years. For a number of variables we are missing the 2005 observation.
[15] To put these numbers in perspective, 47 of the 87 countries experienced a drop in fertility of over one child per woman during the sample period; both the mean and median change in fertility experienced by a country over the sample period exceeded one. Also, over a quarter of the period-on-period changes of the real effective exchange rate exceeded 15%.
[16] Further sensitivity analysis is contained in the older and longer version of this paper.
[17] Our measure is taken from the IMF's WEO data set and includes the relative prices of a country's exports/imports of both goods and services.
[18] The lagged dependent variable is significant and has a coefficient of around .5; adding it reduces the sample size considerably.
[19] The Barro-Lee data set is available at http://www.cid.harvard.edu/ciddata/ciddata.html. We do not use the 2000 education estimates.
[20] We have also experimented further with instrumental variables, using the Hall-Jones measure of "social infrastructure" as an IV for the real GDP ratio, and using lags of regressors as IVs for themselves. These experiments do not change any of our conclusions substantially.
[21] A level-level alternative results in similar conclusions.
[22] It is thus a scatter-plot of residuals; the regression line has precisely the same slope as that reported in Table 1, by the Frisch-Waugh theorem.
[23] The non-parametric relationship is estimated with locally weighted regression, using a band width of .5.
[24] Herbertsson and Zoega (1999), Helliwell (2004), and Higgins (1998) provide analysis and related results.